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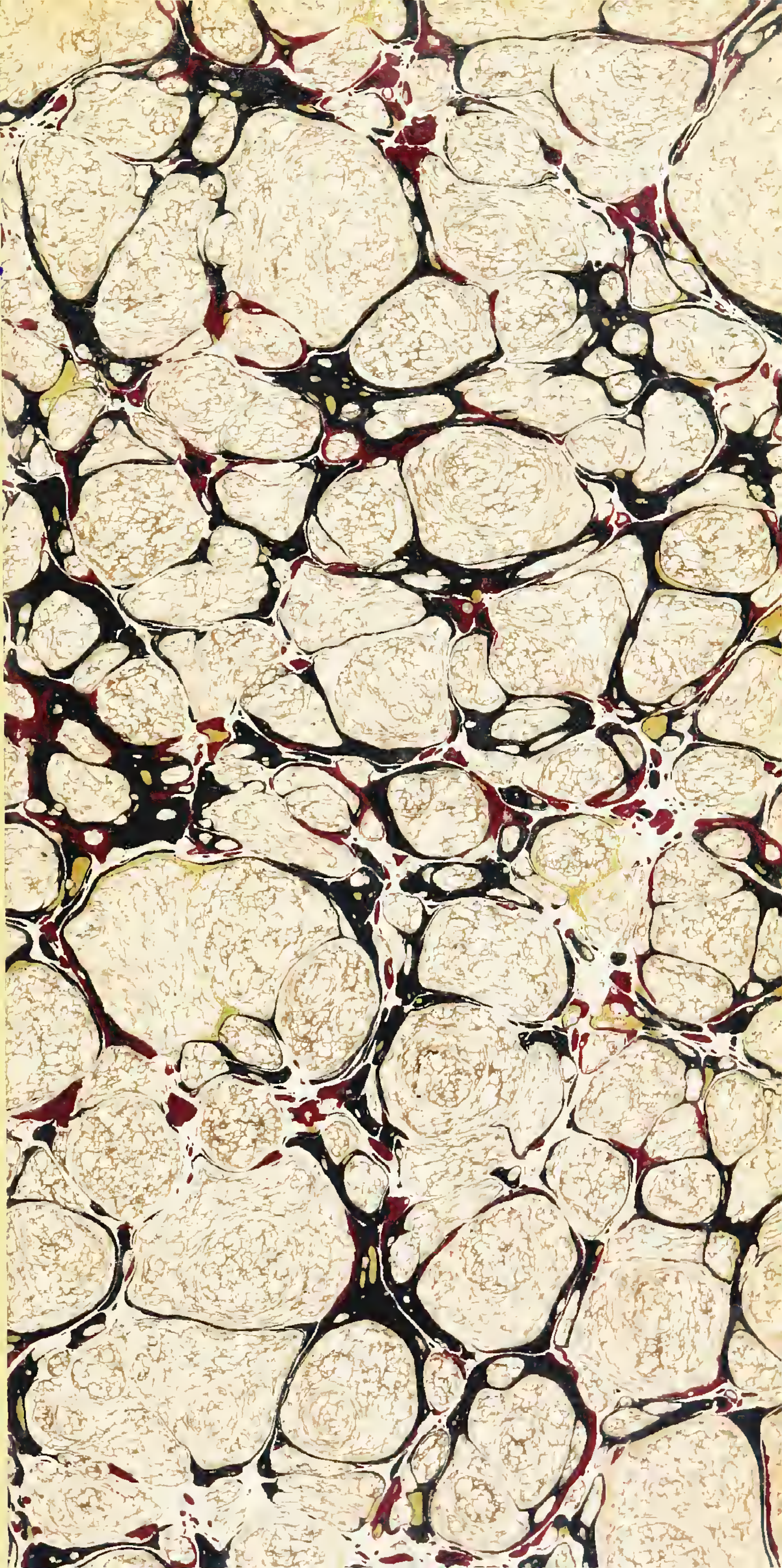

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ENGLAND AND WALES.
EXPLANATION OF SHEET 348.

THE GEOLOGY
OF THE COUNTRY AROUND
PLYMOUTH & LISKEARD.

BY

W. A. E. USSHER, F.G.S.

WITH NOTES ON THE PETROLOGY OF THE IGNEOUS ROCKS BY

J. S. FLETT, M.A. D.Sc.

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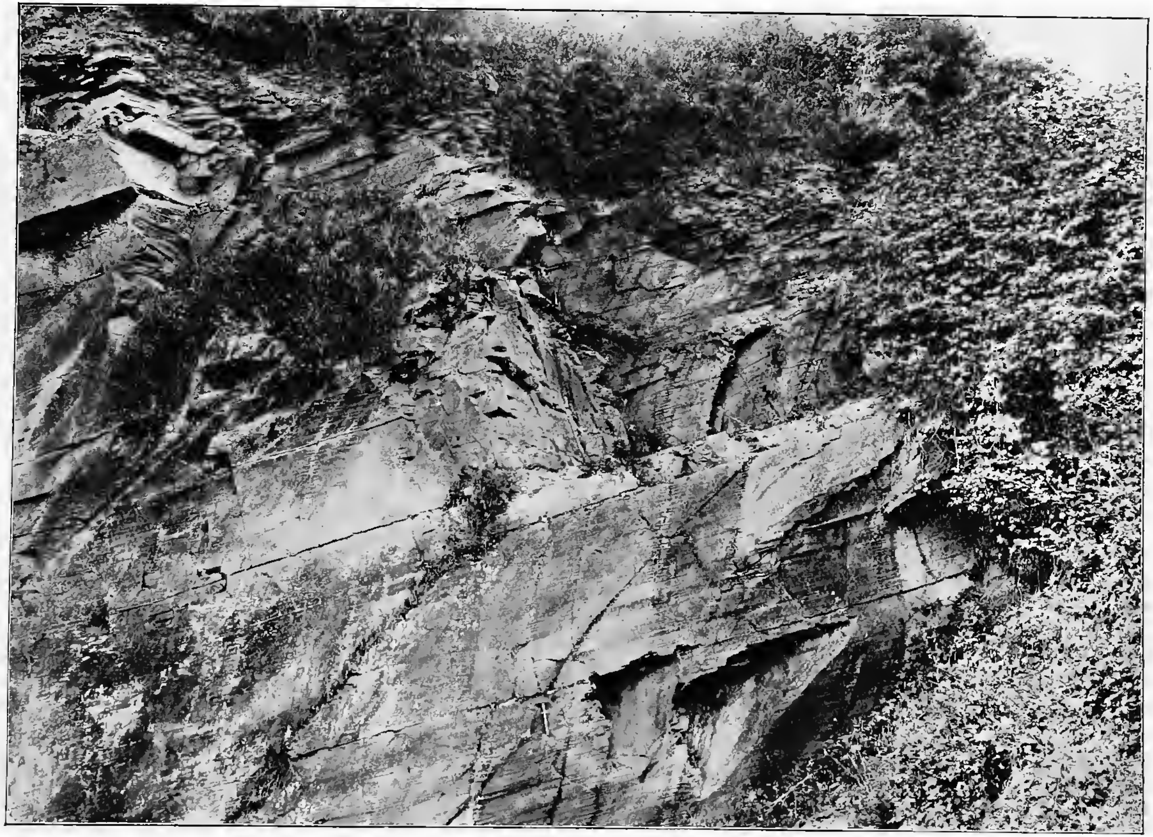

Quarry west of Lamellion. Middle Devonian Slates showing vertical bedding.

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PREFACE.

The original geological survey of this area by De la Beche was published during the years 1834 and 1835, almost wholly on Sheets 24 and 25 of the old series one-inch maps. These sheets were revised in 1839, when the "Carbonaceous series" was separated from the "Grauwacke series"; and about the year 1846 (or 1845) the classification and colouring were modified. De la Beche then adopted the term Devonian Rocks, and stated on the index of colours that they were represented by "A provisional colour, as there is reason to consider that the rocks included under this head in Cornwall and Devon are equivalents of Carboniferous Limestone, Old Red Sandstone, and Upper Silurian Rocks." The igneous rocks and the Devonian limestones were separated from the mass of slates and grits on De la Beche's map, but the succession of the rock-groups, and the intimate structure of the area had not been determined.

In his monumental 'Report on the Geology of Cornwall, Devon and West Somerset,' published in 1839, De la Beche described the leading types of rock, and made many suggestions with regard to their correlation that have not stood the test of later detailed researches. Nevertheless, his facts were noted with such precision that the present author, from experience he had gained in the Devonian area of South Devon, was enabled so to interpret De la Beche's observations as to be able to give in 1890 a forecast of the probable structure in the Devonian rocks of Cornwall. Mr. Ussher then represented on a small map of that county the equivalents of the main divisions which with great care and labour he had established in Devonshire. It is interesting to find that the great structural feature in the Plymouth area, the faulting that displaces the Lower Devonian rocks and brings them for some distance against Upper Devonian, was depicted on that map of 1890, and that the main sub-divisions, which Mr. Ussher has established in Devonshire, have been confirmed by the detailed work since carried out by the Geological Survey.

The area represented by this map was surveyed on the six-inch scale by Mr. Ussher, who has also written the memoir. The petrology of the igneous rocks has been dealt with by Dr. J. S. Flett, and Mr. D. A. MacAlister has contributed particulars relating to mines and minerals. The author of the memoir has given an historical account of the progress of geological knowledge in the area, and he has also compiled a bibliography which is printed as an appendix.

J. J. H. TEALL,
Director.

Geological Survey Office,
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123 N.E.	N. Plymouth	1893–94.
123 S.E.	S. Plymouth	1893–94 (Parts of Cornwall 46 and 55).

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GEOLOGY

OF THE COUNTRY AROUND

PLYMOUTH AND LISKEARD.

CHAPTER I.

INTRODUCTION.

The land area comprised in Sheet 348 is about 166 square miles, of which 27 square miles on the east side of the Tamar is in Devon, the rest in Cornwall. Of this area more than 100 square miles lies within the catchment basin of the Tamar and its tributaries, the Lynher and Tavy. The western part of the map is drained by the confluent East and West Looe rivers, and between their catchment basin and that of the Lynher a narrow strip of about 19 square miles forms the drainage area of the Seaton.

The coast line extending from Plymouth to Polperro is breached by the Tamar estuary, opening into Plymouth Sound opposite Drake's Island, and by the outlet of the Seaton river and the Looe estuary. Rame Head promontory separates Plymouth Sound from Whitesand Bay. Looe Island lies off the coast between Looe and Portnadler Bays.

The Three Towns, Devonport, Stonehouse, and Plymouth (all but its eastern suburbs), are within the eastern border of the map. Besides the towns of Liskeard, Looe, and Saltash. there are numerous large villages and hamlets in the area, amongst which Beer Alston, Tamerton Foliott, St. Germans. Torpoint, Millbrook, and Polperro may be mentioned.

The coast scenery is fine, more especially near Rame Head, Sharrow Point, St. Germans Hut, and Polperro, and the varied colours of the Lower Devonian rocks which form the cliffs add in no small degree to its picturesque aspect.

The very hilly character of the country tends to circumscribe the views in the inland districts but the river scenery is very attractive, the quiet sylvan aspect of the Looe and Seaton valleys contrasting with the life and motion of the lower ship-studded reaches of the Tamar. The greatest elevation, 660 feet, is attained by the Lower Devonian rocks in Bin

Down, between Looe and Menheniot. The Culm Measures at the northern border of the map, near Viverdon Cott, attain an altitude of 600 feet. There are no large stretches of flat lands in the area, the lower grounds near Torpoint and Botus Fleming being of a more or less undulating character as they recede from the shores of the creeks. As a rule the sides of the valleys are steeper in the Lower Devonian than in the Middle and Upper Devonian districts. The influence of geological structure is further exemplified by the dominant feature usually accentuating the Lower Devonian outcrop, and by the bolder hills and crags of diabase and of the harder varieties of volcanic rocks encountered in the Middle and Upper Devonian slate districts. This map is the introduction to the Devonian Geology of Cornwall, as the Torquay map may be considered to be in regard to South Devon, and besides linking the one area to the other, it displays a greater variety of Carboniferous and Devonian rocks than any other map in Cornwall.

Literature.

The late R. N. Worth contributed to the Plymouth Institution, in 1875, a paper on 'The Geology of Plymouth,' in which an admirable summary of the views of general and local observers, prior to that date, is given as far as they relate to the rocks found in the Plymouth district. The labours of the local geologists, John Prideaux and the Rev. Richard Hennah, are specially referred to. To the former we are indebted for a very early account of the geology of the neighbourhood, published in 1830; to the latter for a series of observations on the Plymouth limestone, in which he was the first to point out the presence of organic remains.[1] In 1822 he published 'A Succinct Account of the Lime Rocks of Plymouth' (8vo, Plymouth and London). Prideaux and Hennah wrote about the existence of veins in the Plymouth limestone in 1823. Bellamy's 'Natural History of South Devon' also refers in part to this district.

After quoting Playfair's opinion (1802) on the primary aspect of the Plymouth rocks, Worth proceeds to sketch the evolution of the Devonian rocks as a distinct group, at first called Greywacke by De la Beche. The great work of Sedgwick and Murchison in blocking out the main groups of Carboniferous and Devonian in 1839, and that of Lonsdale in showing the true position of the latter in 1837, is referred to.

The controversy as to the equivalence of the upper divisions of the Devonian to the Lower Carboniferous, and of the lower part to the Old Red Sandstone opened by Jukes in 1866 as regards North Devon, and in 1868 as regards South Devon and East Cornwall, with Etheridge's reply, and Pengelly's opinion, is then touched on.

From the general geology of the district which succeeds it will be seen that Worth, in common with all previous observers, regarded the slates and volcanic rocks on the north of the Plymouth limestone as the older, and the slates and grits on the south of it as the newer, rocks. The section from Mount Batten southward is then given in parallel columns recording the observations of Sedgwick and Murchison, of Phillips, and his own remarks. As this section is for the most part within the border of Sheet 349, it is only necessary to remark that the Dartmouth slates which form a conspicuous part of it from Andurn Point southward are not specially referred to in any of the columns. Nor is there any reference to the Polperro beds or to the occurrence of similar strata in the Plymouth section. There is no allusion to the work of the Rev. D. Williams in this district in Worth's paper. Williams contributed an important paper on 'The Killas Group of Cornwall and South Devon' to the Royal Geological Society of Cornwall in 1843. In this paper he traces the fish-bearing killas from Man Sands by East Allington and Aveton Gifford to near the mouths of the Erme and Yealm, as a syncline from Slapton Sands to Bigbury Bay, everywhere resting conformably on the red and grey grits and red slates of the metalliferous killas (his Killas Group No. 3). He further notes that these beds form the greater part of the cliffs round Whitsand Bay, where they seem to pass into and underlie the metalliferous killas; that they set on at Hannafore, and at Hendrasick (Hendersick) Cove are cut off against Killas No. 3. From thence he traces the fish-bearing killas into the Fowey and Lostwithiel districts with remarkable accuracy. It would thus appear that Williams had anticipated my detailed work in tracing the Dartmouth slates to Polperro by about 45 years. He correlates the Plymouth limestone with the calcareous rocks of Looe and Hessenford. In a supplement communicated later he gives the concordant opinions of De la Beche, Sedgwick, Murchison, and Phillips as to the [Staddon] grits being above the Plymouth limestone. Minard's Cross and other places in the area are mentioned.[1]

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[1] See Appendix.

In 1867-8 Jukes[2] correlated the [Staddon] grits with the Coomhola grits of Ireland, and suggested an inverted anticlinal structure in them bringing them well under the Plymouth limestone. He gave an admirable section from Berry Head to Start Point, in which the Dartmouth slates are correlated with the Old Red Sandstone, and shown as a complex anticline.

Holl's stratigraphical paper, communicated to the Geological Society in 1868, is memorable for his insistence on the repetition of the rocks by folds, often inverted. His map affords an excellent illustration of the views he, in common with the earlier geologists, entertained as to the Lower South Devon Group on the north of the limestones and the occurrence of the Upper South Devon Group on the south of them. The considerable unconformity between the Culm and Devonian rocks maintained by him is a necessary corollary to this descending section of the Devonian northward. He perceived the anomalous position of the Petherwin beds on this view, and attempted to do away with the fossil evidence of their Upper Devonian age. S. R. Pattison commented on Holl's paper in 1872, more particularly as regards the position of rocks previously assigned to the Upper Devonian. The revolutionary character of the views set forth in the author's map published in 1891[1] as regards the general succession was pointed out by R. N. Worth in a paper communicated to the same Society,[2] in which they were criticized in a thoroughly fair and scientific manner.

---

[1] *Trans. Roy Geol. Soc. Corn.*, 1846, pp. 122 and 234.

[2] *Journ. Roy. Geol. Soc. of Ireland*, New Ser., vol. ii., pp. 82, 83, and 76.

As regards the Carboniferous rocks of the area, Dr. Holl was the first to point out their occurrence so far south as Painter's Cross. In the vicinity of Beer Alston Culm Measures were detected during the construction of the South-Western Line in 1888, as recorded in the 'Transactions' of the Devon Association for 1889, in which a valuable paper by R. N. Worth on the geology of the railway will also be found. The discovery of radiolarian rocks in the St. Mellion Culm Outlier by Mr. H. Fox was announced in the 'Transactions' of the Devon Association in 1896, a year before the resurvey of that neighbourhood was begun. Subsequent references to the St. Mellion Culm Measures and Lower Culm Outliers near Tamerton Foliott will be found in papers published by the Somerset Archæological and Natural History Society in 1900, and by the Institution of Mining Engineers in 1901. The grits of Wearde and St. Erney are wrongly included in the Culm Measures in these papers, as the slides examined exhibited no traces of volcanic origin.

De la Beche seems to have regarded the Trappean rocks of the St. Budeaux, Saltash, and St. Urney districts as mainly contemporaneous tuffs and lavas, and in the mention[3] of the associated greywacks being "occasionally arenaceous" may have referred to these grits.

R. N. Worth in 1886 speaks of these sandstones as "tuffs."

In the well-known work of J. A. Phillips 'On the so-called Greenstones of Central and Eastern Cornwall' (1878) several occurrences of intrusive and contemporaneous igneous rocks in this district are specially referred to. He regarded the crystalline greenstones as dolerites of which examples from Hatt, Cumble Tor, Grove by the Lynher, Burraton Coombe, Antony Passage, and Forder Lake (Wearde) are given. He points out the nature of the changes these rocks have undergone in the processes of uralitization. The presence of mica in the igneous rocks of Popes Mill (between Liskeard and Menheniot), at Wearde (Forder Lake), and in the neighbourhood of Saltash is pointed out. On the north boundary of

---

[1] In *Trans. Roy. Geol. Soc. Corn.*

[2] *Ibid.*, 1892.

[3] Report, p. 63.

Sheet 348, near Tremabe, north of Liskeard, we are approaching the St. Cleer district, and to some of the igneous boulder masses met with and to the hornstones associated with the slates the descriptions of the St. Cleer Downs hornblende-slates and crystalline dolerite by Phillips apply. In this connection the early work of the Rev. J. Rogers in 1822,[1] referred to by Phillips, must not be lost sight of. A series of papers by Worth dealing more especially with the igneous rocks of this area appeared in the 'Transactions' of the Plymouth Institute and in the 'Transactions' of the Devon Association in the years 1886, 1887, and 1888. Two of these, 'Notes on the Igneous Rocks of South-East Cornwall and their Stratigraphical Values,' and 'The Igneous and Altered Rocks of South-West Devon,' are deserving of special attention. In the last mentioned he acknowledges the assistance he received from Professor Bonney and Dr. Teall. The picrite of Clicker Tor, proterobases of Grove, Treluggan, Notter, &c., are specially referred to. The Clicker Tor Rock is figured in Teall's 'British Petrography.' Worth gives a general description of the contemporaneous volcanic rocks with special reference to rocks at Mount Batten, Drake's Island, St. Budeaux, Widey, Honicknowle, St. Andrew's Churchyard, Landrake and other places, amongst which the greywackes of Compton and Crabtree (in Sheet 349) are described as tuffs.

The papers hitherto cited have reference to the general structure of the area. We have now to refer to the work by which the individual subdivisions of the Devonian rocks were brought into prominent notice. In this respect the name of C. W. Peach will ever be associated with the fossiliferous rocks of Looe (sometimes called the Looe beds) and with the variegated slates of Polperro and Talland (proved to be in continuity with the Dartmouth slates).

Peach's earlier papers were communicated to the Royal Geological Society of Cornwall in 1841, 1842, and 1843. In 1841 he gave a list of organic remains found in the Looe beds with localities many of which are to be found in this map in the vicinity of Looe and Millendreth. He named the limestone patches (which I have referred to as 'monticuliporoid limestone' in the Memoirs on the Torquay and Kingsbridge areas) "Cornish entrochal marble," and notes the occurrence of *Spiriferæ, Productæ, Turbinoliæ,* crinoids, &c., at East Looe and Millendreth. In the same paper he records the observation of similar fossils to those of South-East Cornwall in the slates of Meadsfoot Sand near Torquay, and in the cliffs between Paignton and Brixham. The occurrence of fossils at Tregrill Quarry near Menheniot in slates with limestone is also referred to.

In 1843, in a paper on 'The Fossil Fishes of Cornwall,' he notes the discovery of *Cephalaspis, Ctenacanthus, Holoptychius,* with *Bellerophon,* and *Turritella,* as belonging to the Old Red, and of *Onchus* and *Sphagodus* as belonging to the Upper

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[1] *Trans. Roy. Geol. Soc, Corn.*, vol. ii., p. 218.

Ludlow, and cites Sedgwick and Murchison as to the Polperro fish-beds being beneath the fossiliferous Looe beds, and Phillips' opinion as to their being equivalent to the Cornstones of Hereford.

In a letter to Sir Charles Lemon published in the same volume (vol. vi., p. 317), in 1846, Murchison speaks of having regarded the rocks in which Peach's fish were found as "forming the axis of South Devon and Cornwall, which I had always considered to be the oldest in that country," but after the discovery of Silurian *Orthidæ* in Gerrans Bay regarded the Polperro fish-beds with *Bellerophon trilobatus* and *Loxonema lincta*, Phill., as transition beds from Silurian to Devonian. He also states that Sir Philip Egerton considered Peach's fossils enigmatical, more allied to *Bothriolepis* than to *Cephalaspis* and *Holoptychius*, and in general appearance different from any Devonian or Old Red fish he had seen. In a later paper[1] 'On the Fossil Fish of Cornwall' Peach gives the history of his discoveries of these remains in the Polperro slates. In a later paper in the same volume (p. 53) *Loxonema* and *Bellerophon bilobatus* are said to occur in the same rocks as the fish remains. The supposed sponges, *Steganodictya* of McCoy, were pronounced by E. Wyatt Edgell in the *Geological Magazine* of May, 1868, to be *Pteraspis*.

In 1880 Peach noted the abundance of *Scaphaspis cornubicus* (the cephalic plate of a pteraspidean fish) at Polperro.[2]

Dr. Jonathan Couch and Richard Q. Couch contributed papers on fossils and on the occurrence of fish remains in the Dartmouth slates of this coast.

The latter[3] contributed a paper to the Royal Geological Society of Cornwall in 1844, in which he points out the localities on the coast between Looe and Fowey in which fish remains in the greatest abundance and most perfect condition were to be found, and notes the occurrence of *Bellerophon* in the slates of Talland Bay. This paper, entitled 'On the Silurian Remains in the Strata of the South-East Coast of Cornwall,' is of considerable local value.

The rocks of the Liskeard district have been described by John Giles.[4]

This notice was begun by a digest of one of the late R. N. Worth's papers[5]; it fitly concludes with a reference to the work of that geologist, who in the course of a busy life found time to contribute more largely to the geology of this area than any of his predecessors, and to call attention to phenomena that had escaped their observation. Careful as an observer, clear as an exponent, cogent as a reasoner, courteous as an opponent, the name of R. N. Worth is indissolubly connected with the annals of Devon and Cornish geology.

[1] *Trans. Roy. Geol. Soc, Corn.*, vol. ix.

[2] *Ibid.*, vol. x., p. 90.

[3] *Ibid.*, vol. vi., p. 147.

[4] *Ibid.*, vol. vii., pp. 93, 155, 169 and 199.

[5] For titles, see Appendix.

Tables of Formations.

In the following table of the Stratified Rocks met with in Sheet 348, the cavern deposits and the division between the upper and lower parts of the Upper Devonian cannot be indicated on the map. As will be seen later, the separation of the Middle from the Lower Culm and of the Upper from the Middle Devonian is in some cases very unsatisfactory:—

RECENT AND PLEISTOCENE.	Estuarine mud		In Tamar and Tavy estuaries and creeks.
	Alluvium		Of E. Looe R. of Tamar creeks and of Seaton Valley.
	Gravel and sand beaches		Whitesand Bay, Downderry, &c.
	River Terrace deposits		Of R. Fowey, Ashford Bridge. Of R. Tavy, near Buckland Abbey.
	Head		Picklecombe, Kingsand, Hannafore, Downderry.
	Raised beach		Looe Island, the Hoe.
	Cavern deposits		Oreston, Stonehouse, Catdown, Hoe.
NEW RED SERIES.	Breccia		Cawsand Cellars, Near Andurn Point?
CARBONIFEROUS.	Middle Culm Measures		Beer Alston, St. Mellion.
	Lower Culm Measures	Posidonomya Beds	Haltonquay. Herod Down.
		Chert Beds (*Kieselschiefer*)	Pillaton.
UPPER DEVONIAN.	Upper part (*Fammenien*)		Beer Ferrers, &c.
	Lower part (*Frasnian*)		Ince Castle Coast. Warren Point.
MIDDLE DEVONIAN.	Plymouth limestone and slates replacing it, with volcanic rocks		Plymouth to Millbrook. Drake's Island.
	Slates (*Eifelian*)		Mount Edgcumbe Park. S. of Liskeard.
LOWER DEVONIAN.	Staddon grits (*Upper Coblenzian*)		Staddon Point, Maker. St. Keyne, &c.
	Meadfoot group	(*Lower Coblenzian*) (*Taunusian*)	Millbrook, Tregantle, Looe.
	Dartmouth slates (*Gedinnian*)		Rame, Portwrinkle, Polperro.

The following is a table of the Igneous Rocks, with some of the localities where the types may be seen:—

Contemporaneous Igneous Rocks.	Schalstein tuffs	N. of Mill (S.E of Kings Tamerton), Drake's Island, Wearde Quay.
	,, lavas (mostly highly vesicular andesitic basalt or spilites)	Hartley Reservoir, St. Budeaux, Brightor, Raglan Barracks, Lollaberry Quarry near Saltash, &c.
	,, ,, showing pillow structure	Near Henn Point south of Saltash, Devonport Workhouse Quarry near Ford.
	,, ,, porphyritic not vesicular	Near Penquite (south of Pillaton), &c.
Intrusive Igneous Rocks.	Diabase	Burraton Coombe quarry, Poldrissick by R. Lynher, dykes on coast south of Maker.
	Mica diabase	Quarry in Defiance Quay Lawn, &c.
	Dolerites	In Antony Park.
	Hornblende dolerites or proterobases	Between St. Budeaux and Saltash Bridge. Forder Lake, by R. Lynher at Grove and Treluggan, &c.
	Picrites	Near Criffle Mill (S.W. of Molenick), Clicker Tor and Menheniot Station.
	Lamprophyre	On either side of R. Tamar at North Hooe Ferry.
	Felsite	Kingsand, Withnoe.
	,, dykes	1 mile S. of Beer Alston Church, near Collytown and Lopwell.
	Trachyte (?) silicified	Quarry on Bin Down.

Cartography.

The area of Sheet 348 is mainly included in Sheets 24 and 25 of the old Ordnance Geological maps, but its western border enters Sheets 30 and 31. These maps pourtray the geology of the area as one unsubdivided formation, the Devonian, Apart from dips the details consist of:—A fairly accurate representation of the extension of the Plymouth limestone and of its termination at Cremyll; a lenticular patch of limestone crossing the Seaton valley, south of Hessenford, in a north-easterly direction; a series of lenticular patches and strips of greenstone generally striking east and west, and occurring at intervals in the line of country extending from Ford and St. Budeaux by Saltash and Menheniot to the vicinity of Liskeard; a patch of serpentine at Clicker Tor, Menheniot Station; and two patches of columnar porphyritic rock, the larger on the shores of Cawsand Bay the smaller near Withnoe.

When we turn to Chapter III. of De la Beche's Report we find that the structure of the district is interpreted by the dips and strikes of the rocks, to a great extent independently of their lithological characters, and that taking the Plymouth limestone as an horizon the rocks with greenstones or 'schistose trappæan' bands on the north were regarded as older than the Plymouth rocks.

The calcareous fossiliferous rocks of Looe, in which are included the limestones south of Hessenford and the variegated slates of Talland and Polperro, are specially mentioned. The former (pp. 78, 79) were thought to pass eastward into the slates with trappean rocks of St. Stephens and Saltash, the latter were supposed (p. 81) to agree in geological position with the Plymouth rocks, whilst calcareous beds (the same series as that south of Hessenford) on the coast of Whitsand Bay between Trewinnow and Tregantle were regarded as the probable prolongation of the Plymouth limestone westward.

Correlations such as the above tended to confuse the succession of the Devonian rocks, which through reliance on direction of dip had been taken as a descending one from the Plymouth limestone northward, and in consequence the structure of the Devonian rocks of Cornwall, to which the area comprised in Sheet 348 furnishes the key, remained practically unknown until the year 1890.

In that year the resurvey of the Devonian rocks in the Torquay and Totnes area had sufficiently advanced to put the writer in a position to dissever the facts given in Chapter III. of De la Beche's Report from the suggestions as to correlations with which they were interwoven. It then became apparent that the succession had been misread through reliance on cleavage dips and reversed dips in bedding, and that the existence of a great structural faulting, by which the Lower Devonian outcrop was shifted from Mount Edgcumbe northward toward Menheniot, had been overlooked. This faulting cuts off Upper and Middle Devonian rocks on their strike against the subdivisions of the Lower Devonian. For example, near Bonialva, north of Hessenford, red and greenish slates of the lowest subdivision of the Lower Devonian (the Dartmouth slates) are brought into proximity to, if not actual contact with, red and green slates in the Upper Devonian.

The confounding of Upper, Middle, and Lower Devonian rocks in the same minor subdivision, which makes the perusal of Chapter III. of De la Beche's Report a laborious pastime, is readily explained by the apparent continuation of Lower Devonian rocks by Upper and Middle Devonian as they were followed eastward without detecting the fault between them. The Devonian Geology of Cornwall as given in the Report was remodelled in accordance with facts brought to light by recent researches in 1890, and the results, illustrated by a little map constructed solely from the information supplied in Chapter III., were published in the 'Transactions' of the Royal Geological Society of Cornwall in 1891. This little map shows the main divisions of the Devonian with approximate accuracy, and also a generalized representation of the great structural faulting mentioned above. A comparison between it and the present map, the result of detailed survey on the 6-inch scale, will show the additional facts which have been since discovered and the real structure and relations of the Lower Devonian subdivisions. The most prominent addition is the mass of Culm rocks about Pillaton and St. Mellion, largely composed of sandstones (Middle Culm), which exhibit unconformable relations to the Upper Devonian slates, on which they rest directly in part, and in part on intervening Lower Culm Measures of variable thickness and irregular development. The outliers of Lower Culm near Tamerton and the grits of Wearde and St. Erney (probably in the Upper Devonian although a Middle Culm age had been with much hesitation assigned to them), are also brought out in the detailed survey.

As regards the Lower Devonian subdivisions the principal alteration is in the inclusion of the fossiliferous beds of Looe in the Meadfoot Group and the consequent establishment of the Dartmouth slates as an underlying subdivision. This fact was however brought to light by the comparison of the Devon Coast sections with this area subsequent to the survey of the Looe district in 1899, as mentioned in the Memoirs on the Geology of the Torquay and Kingsbridge areas. It was to some extent foreshadowed by the alternative rendering of the Watergate Bay slates as an anticline, and the consequent correlation of the Newquay beds with the Meadfoot beds, shown in the little sketch map of 1891. The present map shows the faulting of the Lower Devonian outcrop to have been effected by two parallel faults, but the evidence proved insufficient to permit of these faults being traced northward beyond the points where they ceased to affect Lower Devonian rocks. It was also found impossible to fix on a satisfactory boundary which should show the real relation of the Middle and Upper Devonian slates. The generalized boundaries shown on the little map of 1891 cannot in this respect be improved on, but the Botus Fleming anticline must be included in the Upper Devonian.

General Geology and Structure.

The main outcrop of the Lower Devonian as indicated by the Staddon Grit developments in the published maps of Devon, Sheets 349 and 350, runs irregularly westward from near Sharkham Point more or less along the 50° 23′ parallel of latitude to the Avon valley, whence it descends to parallel 50° 21′. The Staddon grits of Staddon and Mount Edgecumbe are on this parallel (50° 21′), and if their normal outcrop had not been shifted by fault, its westerly continuation (allowing for deflections) would lie south of the coast between Tregantle and Downderry and would cross the western margin of the map near Pelynt between parallels 50° 22′ and 50° 23′, or further to the south. At Cawsand, however, a great north-west fault brings up the Dartmouth slates, cutting out the Meadfoot Group. This fault will be referred to as the 'Cawsand fault'; it is not seen in section owing to coincidence with a drainage channel on the coast, and owing to complications inland produced by minor tributary dislocations; it is, however, to be seen in the old cutting through which the guns were brought to Scraesdon Fort on the north-west of Antony. The Cawsand fault shifts the main outcrop of the Staddon grits to Earth Hill on parallel 50° 23′, here they resume their normal westerly trend for two and a half miles to the west, when they are again cut off and shifted by another great north-westerly dislocation. This second fault, which will be referred to as the 'Portwrinkle fault,' is obscure on the coast at Portwrinkle where it only affects the Dartmouth slates; but although nowhere seen in actual exposure, its course by Trewrickle, Rosedale, and Catchfrench can be satisfactorily traced to the vicinity of Menheniot Station, where the Staddon grits reappear and resume their normal westerly trend on parallel 50° 25′, or 2′ further north than their northernmost main outcrop in Devon.

The general relations of the Upper, Middle, and Lower Devonian Groups are so affected by these faults that they cannot be considered without reference to them. It will not be necessary here to refer to the dislocations, some of considerable magnitude, which affect the relations of the minor subdivisions, and these will be reserved for the general notes in the chapters devoted to each group. Only the Mount Batten and Staddon projections of the east coast of Plymouth Sound are included in this map. The slates with limestones and volcanic bands which bridge over the interval between the Plymouth limestone and Staddon grits are well represented in Batten Bay; they occupy the north part of Mount Edgcumbe Park. The southern shores of St. John's Lake are presumably in the Middle Devonian, but as the Torpoint and Deadman's Point rocks on the north side of the Lake are Upper Devonian, it is necessary to assume that the Middle Devonian Series is either partly cut out by fault or much less repeated by folds than the other groups. The discovery of characteristic fossils here and there and the recurrence of lithological types makes it very evident that from Plymouth and Antony northward Upper Devonian rocks are constantly repeated by folds, and without fossil evidence it is impossible to say to what extent Middle Devonian may be represented by dark slates which largely occur in the Upper Group. From Antony to Earth the Cawsand fault separates Upper Devonian on the east from Staddon grits on the west, and at Earth Upper Devonian from Middle Devonian slates, but beyond this it is concealed by alluvium for three-quarters of a mile. Prolonging the direction of the fault north-westward we find that it coincides with the course of the River Tiddy above Tilland. Between this assumed prolongation of the Cawsand fault and the Portwrinkle fault we have referred the rocks south of the St. Germans schalstein mass to the Middle Devonian, and this mass may perhaps be included in the same series.

How far we are entitled to entertain the possibility of the occurrence of anticlines of Middle Devonian in the Upper Devonian area north of the St. Germans schalstein mass depends on the extent to which the lower beds of the Upper Devonian are represented by dark slates with occasional calcareous beds or limestone bands. Occurrences of dark slates without fossil distinction may be referred to the lower horizons of the Upper or to the upper horizons of the Middle Devonian. This question involves the stratigraphical value of the purple, red and green slates. Locally, there can be no question as to the value of this colour distinction as characteristic of beds in the Upper Devonian just as similar variegated colours are characteristic of the Dartmouth slates in the Lower Devonian, but actual investigation proves that coloured slates may occur in dark grey slates and *vice versâ*, even in the Middle Devonian and from the Middle Devonian upward. That is to say, the downward extension of the colouring matter is purely local, and no delicate points in stratigraphy can be based on it. Near Botus Fleming the occurrence of *Styliola* in the dark grey slates favours their inclusion in the Upper Devonian. The same fossil has been found in slates associated with limestone beds in Treskelly Quarry near the western end of the St. Germans schalsteins. *Styliola* also occurs in the purple and green slates with cyprids near Padderbury, Menheniot, and other places. Mr. Howard Fox's discoveries of Frasnian (lower part of Upper Devonian) fossils in black slates at Trevone with *Styliola* in a country where purple and green slates with volcanic rocks occur, prove the diagnosis made in 1891 as to the Upper Devonian age of certain rocks in that part of Cornwall to be correct, and that they are the same or similar types to those in this area.

Following the Portwrinkle fault from Rosedale, where the St. Germans schalstein terminates, by Catchfrench toward Menheniot Station, the prevailing type is dark grey slate, purple and green being only conspicuous on an east and west strike through the 'school' on the map; and this is the case cited previously, where variegated slates of the Lower Devonian and of the Upper Devonian are in juxtaposition on either side of a great structural fault. There is reason to think that the Portwrinkle fault forks on crossing the Seaton river valley, the main dislocation cutting off Staddon grits against either Upper or Middle Devonian slates on the north, the branch fault shifting the easterly termination of the picrite of Clicker Tor and some volcanic bands on the north of it. In neither direction can these faults be further followed. The purple and green slates of Coldrenick, Doddycross and Menheniot do not cross the Seaton river valley, in fact the slates in which the volcanic masses occur on the north of a line drawn from Tregrill near Menheniot eastward by Padderda Wood to Tilland, toward Tresandra, and thence northward across the strike of the volcanic rocks through Blunts and Holwood to Pillaton, are grey, dark grey, and greenish, very rarely, if ever, purple. The variegation is therefore local, and to some extent, at least, independent of stratigraphical horizon. Moreover the pale greenish slates which take the place of the variegated beds between Pillaton Mill and Trebeigh Wood on the north margin of the map, give place to dark grey slates which may represent the lower beds of the Upper Devonian, as near Merrymeet the rocks are of a similar character to the Middle Devonian coherent argillaceous slates of the Liskeard and Moorswater district. It is quite possible that the dark slates of the Upper Devonian may extend westward along the northern margin of the map from Trebeigh Wood through Tremabe, Trethinnick, and Trewartha, but I should be certainly inclined to refer the bulk of the slates south of these places to the Middle Devonian. Without fossil evidence or marked lithological character it is unsafe to carry the process of delimitation of the Upper and Middle Devonian further; probably tongues of the former cross the Seaton valley in synclines westward, and anticlines of the latter dovetail into the Upper Devonian area eastward.

Near Tremabe the rocks come within the aureole of metamorphism of the Bodmin Moor Granite, and here we encounter dark platy slates or shales and rocks approaching hornstone with clusters of diabase boulders, in places recalling the rocks in the vicinity of the granite of Dartmoor near Brent and Ivybridge.

The Culm rocks of Pillaton and St. Mellion form the southern part (or half) of a large outlier, the north border of which is in Sheet 337, at from three to four miles south of the main Culm boundary near Tavistock. The outlier of Pentillie and its fault-shifted continuation within the bend of the Tamar on the Devon side is the most southerly of a series of outliers which occur in the adjacent map on the north of Beer Alston. These outliers are composed of soft and hard beds of felspathic sandstones, or greywacke, associated with dark shales which contain plant traces, and with one exception (Beer Alston Station) rest directly on Upper Devonian slates.

The main outlier consists mostly of greywacke sandstones, varying from coarse to very fine grained, nowhere conglomeratic or even very coarse grained beds. The dark shales locally prevail. The sandstones are frequently parted by even bands of grey shale or mudstone, and even interlaminations of these materials occur, with local signs of current bedding. In all these respects they have their counterparts in the greywackes of Wearde, south of Saltash, of Efford and Compton in the adjacent map (349), and in the Bovey Tracey, Newton Abbot, and Chudleigh districts in Sheet 339.

The Lower Culm is represented in the places shown on the map and at Haltonquay, where, besides radiolarian chert in dark shaly beds, slaty brown-weathered mudstone crowded with *Posidonomya becheri* Bronn occurs. The Haltonquay Lower Culm is exposed on the margin of the Tamar alluvium, beneath which it is cut off on the east by a fault; on the west it is immediately overlain by the greywacke series and cannot therefore be shown on the map. West of Pillaton the greywacke of Herod Down rests on *Posidonomya*-beds of the type met with near Ashton, &c., in the Chudleigh district. In this patch, as also near Pillaton on the east, the chert beds and associated hard shales and mudstones are represented, and where exposed in section are shown to be excessively contorted. The occurrence of Lower Culm near Dunnerdake where shown on the map is exceedingly doubtful. At Newton Ferrers there are dark banded mudstones in the Lower Culm which is in places bleached to pale greenish white, very like certain mudstones locally found in the Upper Devonian. On Amy Down there is an anticline of Lower Culm surrounded by the greywacke series. In this western part of the outlier the boundary with the Upper Devonian is clearly faulted, the greywacke series rests on Lower Culm, but the conformable nature of the junction is very questionable. East of Amy Down and Pillaton the greywacke series is shown to rest directly on Upper Devonian brought up by faults east of Amy Tree and of Viverdon Cott, but, to all appearance, in unfaulted contact in the Polborder inlier, east of St. Mellion and west of Haymarsh. Lower Culm dark hard mudstone shales and chert beds occur in irregular patches east of Pillaton, at Rouse, and north of Polborder. The relations of these patches to the greywacke series are often very obscure through defective evidence, which applies especially to the westerly termination of the Rouse and Polborder patch and to the northern boundary of the Pillaton mass. Near Painter's Cross these cherty Lower Culm rocks are faulted against the Devonian. West of the Pentillie outlier cherty beds of the Lower Culm also occur. The evidence, therefore, in this part of the outlier points to the thinning out of the Lower Culm beneath the greywacke irregularly eastward. From this we are forced to conclude that before or during the accumulation of the greywacke series the Lower Culm was denuded irregularly, so that patches of it were left here and there. The only escape from this conclusion is to regard all the apparently normal contour junction boundaries between the greywacke series and the Upper Devonian as nearly horizontal thrust faults, and this does not seem at all probable.

The Tamerton outliers are between three and four miles south-east from Painter's Cross and Pentillie. The larger consists of hard, dark Lower Culm with signs of decomposed volcanic rock along a part of its southern margin. The smaller of dark radiolarian chert with quartz veins, excessively contorted. I could not trace any faults in the vicinity to account for the position of these outliers and their north-westerly trend. Near the smaller one the purple and green Upper Devonian slates contain cyprids. The calcareous beds of Landulph cross the Tamar eastward, and with occasional lenticles of limestone are represented on the shores of Tamerton Creek. I think we may conclude that the slates and mudstones of the Upper Devonian, which contain *Spirifer verneuili* Murch, &c., between Beer Alston and Beer Ferrers may strike west beneath the main outlier, but that they are rather higher in that series than the slates on which the Tamerton Lower Culm outliers rest; if this is the case it points to an unconformity between the Lower Culm and Upper Devonian, but this will not in any way invalidate the conclusion that the chief unconformity is between the greywacke series and the underlying beds.

Beds of grit and greywacke (Wearde grit) are found among the Upper Devonian slates and volcanic rocks at intervals between Wearde Quay (south of Saltash) and Trehunsey Bridge (west of Quethiock). Their greatest developments are between Wearde Quay and Forder Creek, and on either side of the River Lynher, north of Trevollard, and north and east of St. Erney. From here to Padderda Wood, a distance of three miles, no signs of their occurrence have been met with. At Padderda Wood dark blue brown-weathered siliceous rocks, partly banded, are exposed *in situ*; similar rocks are present in the greywackes at Compton, near Plymouth. At about half a mile north of Padderda Wood fragments of greywacke occur on the summit overlooking the stream valley east of Coombe. The grey slates near this exhibit a banded appearance in places. The only further evidence of the greywacke is furnished by surface fragments above the wood on the west side of the River Tiddy, just north of Hepwell Bridge.

In none of the exposures of Wearde grit have traces of plants or of organisms of any kind been found in the greywackes or in the dark shales and slates associated with them, and microscopic examination proves that the greywackes are largely made up of the débris of igneous rocks, although in the quarry at Wearde and elsewhere rocks approaching to the character of quartzites occur in them. Although wherever they are well exposed the even-bedded greywackes show a marked contrast to the surrounding strata, no proofs of their superposition as a distinct series have been met with. Their relations to the slates and volcanic rocks are everywhere such as might be expected were they an interbedded and impersistent group, and volcanic bombs occur in a thick bed in the lower part of the grits at 'Defiance' Quay lawn at Wearde, where they rest on diabase, also in the railway cutting above, in which the thick slates interbedded contain seams of felspathic-tuff with slate fragments. On the other hand, the resemblance of these rocks to the Culm grits and greywackes of the St. Mellion outlier, and to the beds of Ugbrooke Park and of the outliers between Newton Abbot and Ipplepen is marked. Evidence of unconformable superposition is clearly manifested by the greywackes of the St. Mellion outlier. The absence of coarse beds, other than tuffs, in the Upper or Middle Devonian slate areas of South Devon and Cornwall as far as is known, coupled with the occurrence of chert beds interbedded with the lava near Henn Point on the Saltash coast, tended to make a very strong case in favour of the assignment of a Culm age to these greywackes. This opinion was expressed[1] on the assumption that these cherty bands and fragments of a similar character in the greywacke near St. Erney were Lower Culm. In neither case have radiolaria been found, and the probability of their being Devonian cherts locally accompanying andesitic basalt flows (as is often the case where pillow lavas occur in other formations) is strong.

As regards the volcanic rocks of the area, the schalsteins and vesicular rocks of Mount Batten coast, Drake's Island, and St. Germans, as well as those of Liskeard and to the south of Liskeard, near Trethawle, are included in the Middle Devonian. As regards the masses between the north of Plymouth and Pengover Green, it must not for one moment be supposed that the boundaries of these are in all cases definite stratigraphical lines. In places, between Landrake and St. Stephens for instance, they simply denote the separation of slates in which signs of volcanic rock have not been detected from slates associated with one or several volcanic bands probably repeated by folds, in such a manner that individual boundaries could not possibly be drawn on the meagre surface evidence. It is necessary at the outset strongly to insist upon this, because the practice of definite delimitation and colouring adopted by the Geological Survey puts the geologist in such a country as this in the predicament of ignoring unmappable bands of volcanic rock where the general association is of importance, or of drawing lines to include these associations in such variable proportions that in some cases the volcanic seams are in a very infinitesimal ratio to the slates in which they occur, whilst in others there may be infolded seams of slate in infinitesimal ratio to the volcanic rocks; between these extremes there is every gradation.

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[1] *Trans. Instit. Mining Engineers*, 1901 *Proc. Som. Arch. and Nat. Hist. Soc.*, vol. xlvi., 1900.

From this caution it will be apparent that the volcanic rocks of the Upper Devonian area may represent several distinct stages of eruption in the same general period. Furthermore, reference has been made to dark slaty or shaly rocks associated with the Wearde greywackes, to dark slates in the Upper Devonian and to dark slates in the Middle Devonian, as these volcanic rocks occur in an area where the first and last may locally appear through plication, and where the second is naturally present in places, it is impossible to give an exact chronological limit to the volcanic rocks collectively or to arrive at any definite relative succession based on their occurrence at different latitudes. In the Lower Devonian area such feeble traces as have been noted are in most cases much too insignificant to show on the map. It seems, however, probable that during the deposition of the Dartmouth slates and succeeding rocks of the Meadfoot group occasional emissions of tuff or lava may have taken place, but being at best small through shearing, contortion, and thrusting, no volcanic horizons can be actually established.

Lower Old Red Sandstone is bracketed with Dartmouth Slates in the legend to the Index tablet on the map, in accordance with the grouping adopted in the Newquay Sheet. The Author disclaims all responsibility for this, as *Bellerophon* occurs in the Dartmouth Slates, and the homotaxial equivalence to the Lower Old Red is, in his opinion by no means restricted to this sub-division.

CHAPTER II.

LOWER DEVONIAN.

General Structure.

We are now in a position to consider briefly the structure of the Lower Devonian area as shown by the relations of the three subdivisions, viz., Staddon grits, Meadfoot group, and Dartmouth slates. Although it is seldom possible to fix upon definite boundaries between these groups where their relations are normal, yet outside the indefinite junction zone wherein lithological characters are similar they present general distinctions amply sufficient to bring out their relations and structure. Thus in the Staddon grits, whether they form as at Staddon, Mount Edgcumbe, and between Sheviock and Polbathick, a more or less definite grit series, or a mixture of arenaceous and argillaceous mudstones with hard grits irregularly associated as at St. Keyne, the extreme paucity of fossils, the absence of calcareous beds and of volcanic rocks separates them from the rocks of the Meadfoot group.

The Meadfoot group is distinguished by the prevalence of grey slates with few fossils in their upper portion which is homotaxeous with the Lower Coblenzian of the Continent; by irregular grit developments, limestone bands or lenticles, volcanic bands, and by a more or less fossiliferous character, lower down where the rocks correspond to the Taunusian of the Continent. The distinction between the basement beds of this series and the Dartmouth slates is seldom satisfactory, although the two groups are as distinct as the Meadfoot group and Staddon grits. The fossiliferous beds of the Meadfoot group are of the utmost importance in working out the structure of the Lower Devonian area, although their persistence on any particular horizon cannot be relied upon.

Between the Cawsand and Portwrinkle faults, the fossiliferous beds are found west of Millbrook and exhibit a nearly east and west outcrop between St. John's and Trewrickle. They extend southward, however, to the coast at Long Sands and Tregantle, where they are well exposed.

On the south of St. John's it will be seen that the outcrop of the Meadfoot group does not exceed 180 yards in width; it is here bounded on both sides by faults. Reference has been made to the complex character of the Cawsand fault; this is illustrated by a nearly continuous representation of the Staddon grits along it on the map, but this representation is due in my opinion to splitting in the main fault, produced by the crossing of another dislocation seen in Inswork brick pits, and running thence probably toward Maker Church. I conceive the apparent strike of the Staddon grits along the Cawsand fault to be due to position between two faults, so that the slates in Antony Churchyard and at St. John's may be regarded as the base of the Middle Devonian. The geology of Millbrook, St. John's and Antony is most difficult, because the faults are not exposed in section, and the variable rocks of the Meadfoot group are cut off on the west against Staddon grits and slates in a country with no quarries and bad surface evidence. The very irregular boundary of the Dartmouth slates with the rocks of the Meadfoot group is due to the major foldings of the contorted rocks being further complicated by faults. The rocks south of Crafthole may include Dartmouth slates as well as the basement beds of the Meadfoot group; they are mostly grey and *Pteraspis* has been found in them.

On the west of the Portwrinkle fault the Dartmouth slates, from Perdredda to the Seaton valley, appear to be in natural junction with the Meadfoot group, and in faulted junction with it on the west of the Seaton valley. Their south-westerly deflection to the coast near Windsworth is probably continued to a point between Looe Pier and Hannafore Point, where dark grey slates are in natural junction with variegated slates which are continuous without doubt with the Dartmouth slates of Looe Island.

The dark basement slates of the Meadfoot group form the northern cliff of Portnadler Bay, and are cut off by a well marked fault against the Dartmouth slates of Talland and Polperro. This fault runs in a west-north-west direction just south of Hendersick and north of Watergate. Between Watergate and Polean the rocks on the south side of it may belong to the basement beds of the Meadfoot group.

The fossiliferous Looe grits, slates, and calcareous beds occupy a band of country varying from one to two miles in width, extending from Hendersick and Trelawne on the west, through Trenant, Looe, and Millendreath, to the Portwrinkle fault between Hessenford and Perdredda wood. That is to say, fossiliferous horizons are repeated by folds here and there throughout this belt of country. On the west border of the map, however, between Polean, Pelynt, and the outcrop of the Staddon grits, these fossiliferous horizons are either absent or very inadequately represented.

This last observation taken in connection with the changes in dip round Pelynt to which De la Beche calls special attention, would suggest the tapering out of the fossiliferous horizons westward along synclinal folds, an explanation which could not be admitted without the co-operation of cutting-out strike faults. Although from the nature of the rocks affected the position of such a fault, or faults, cannot be proved, there can be little doubt as to its existence not far from the positions shown on the map, for the following reasons:—

The Dartmouth slates form a complex anticline, appearing in a mass on the hill south of Bake wood, and in very irregular plicated association with grey slates, grits, and quartzite, on the west side of the Portwrinkle fault, between Bake wood and Bonialva. On crossing the Seaton valley the variegated slates give place to the grey slates and grits which form the high ground above Lydcott wood and from thence to Bin Down.

On Bin Down traces of fish have been found in hard grits; the variegated slates bound this feature on the north as far as the valley west of Bray, and on the south between Bray and Shorta Cross. In the valley west of Bray the anticline is shifted northward by a north-north-west fault to Wringworthy, whence it continues on the high ground, on the north of Corgorlon (on which, at Corgorlon Tor, there are grits similar to those of Bin Down), westward to the East Looe valley. The Dartmouth slates have disappeared on the east of the road north of Sandplace station, where cuttings display grey slates with hard grit bands on their strike, but on crossing the valley they reappear on a parallel strike in a narrow band which speedily dies out in the direction of Tredinnick.

On the south border of this complex anticline dark slates with grits, evidently inferior to the fossiliferous beds, bound the Dartmouth slates. On its northern margin fossiliferous beds occur in direct contact on the south of Plashford, proving that here at least the northern boundary is overthrust on the fossiliferous beds. At Wringworthy a patch of red gritty beds of characteristic Looe type is cut off against the Dartmouth slates by the fault which here shifts the anticline. These grits are in proximity to the variegated slates on the north of the Bin Down high land, so that the overthrust northern boundary of the mass north of Corgorlon is evidently shifted by the cross fault to a position in the valley on the east of Wringworthy, and the grits at that place are in the angle between two faults. From this angle the shifted fault may continue to the Portwrinkle fault through the rocks of the Meadfoot group, and cease to bound the variegated slates, or it may form their actual boundary. This uncertainty does not affect the argument that strike faults, by cutting out certain horizons, may obliterate or impair the correspondence we would otherwise expect between the rocks of the Meadfoot group on the north, and those on the south of the anticline. The fossiliferous horizons of the south seem to be inadequately represented on the north. On crossing the East Looe valley and passing through Duloe to Pelynt, a district is traversed in which these fossiliferous horizons have not been detected at the surface, so that the continuance of the fault boundary of the anticline south of Plashford is a necessity. A careful survey of this part of the area revealed very insignificant but indubitable signs of the variegated Dartmouth slates just north of St. Ann's (or St. Nun's) Well, and in the West Looe valley adjacent, due west of Muchlarnick. At about 520 yards south of Muchlarnick variegated slates were seen, and fragments of similar character were noticed on the surface at about 200 yards south-west of Muchlarnick. No doubt we should find, if this ground were exposed in section, that greenish slates in this vicinity belong to the Dartmouth slates, and that the variegated exposures have stratigraphical value solely as indicators of their presence, as rough grits also occur in the neighbourhood resembling those of Bin Down and Corgorlon Tor, and of the Portwrinkle coast. A fault is exposed in a quarry where antimony was obtained, between Tredinnick and St. Ann's Well, and there are suggestions of the presence of another at the farm near Muchlarnick on the north-west; so that the position assigned to the faults on the map is not wholly without foundation.

Strike faults, as well as irregular plications, may have something to do with the comparatively thin outcrop of the Staddon grits on the east of the East Looe valley and their development on the west.

The prolongation of the fault in Portnadler Bay, which will be referred to hereafter as the Portnadler fault, has a considerable influence in shifting the outcrop of the Staddon grits from latitude 50° 24′ 40″ to Bodmin on latitude 50° 28′ in the adjacent map (Sheet 347). It is the third great fault which actual survey has proved instrumental in achieving the result theoretically ascribed to one great fault in my little map of 1891.

Besides the faults already referred to there are thrusts and faults of lesser magnitude which cannot be traced inland from the coast, which may in some cases have material effects on the relations of the Dartmouth slates to the rocks of the Meadfoot group.

A thrust is visible in Tregenhawke Cliff (south-west of Millbrook), at about a mile from Sharrow Point. It seems to descend to the beach at 220 yards from its outcrop on the summit, and although on the coast it intersects the Dartmouth slates, it is quite possible that its prolongation inland may affect their relations to rocks of the Meadfoot group. The boundary of the calcareous fossiliferous beds of the Meadfoot group in Black Ball Cliff, about a mile east of Portwrinkle, is a fault which in conjunction with another dislocation separates them from lower horizons of the same group in which the variegated Dartmouth slates appear, but form a very small part of the mass. As *Pteraspis* has been found on the coast, and no certain boundaries can be drawn to separate slates which belong to the Dartmouth group within this mass of contorted rocks mainly belonging to the lower part of the Meadfoot group, it was thought better to colour the whole as Dartmouth slates than to attempt a separation. This course gives prominence to the termination of the fossiliferous rocks. There is also a strong probability of a fault nearly half a mile to the west at Hilstor rock, from whence it appears to run northward to Pool, displacing the north boundary of the fossiliferous rocks in the Meadfoot group south of that place.

On Finnygook beach the Portwrinkle fault is so badly exposed that it suggests the splitting up of that dislocation into branches before reaching the coast, one of which may be the Black Ball Cliff fault. The faults and thrusts observed elsewhere on the coast and in inland localities tend to obscure the complex folds which cause the abnormal appearances of rocks out of their general strike, the inadequate representation of certain horizons, and more especially the difficulty in tracing any structures continuously even in cliff sections.

Although the general strike is east and west, to this there are many exceptions in the Lower Devonian area, and in the coastal districts, between the Rame Head promontory and Portnadler Bay, the strikes range from north-east and south-west, to north and south, an east and west strike being very exceptional. To the north (except south of Trelawne) and east of the Portnadler fault southerly schistosity dips prevail. the rocks are often vertical, but northerly dips are very seldom obtainable. On the south of the Portnadler fault the converse is the case, the dips being northerly or vertical. Northerly dips are also met with on the north of the fault up to a line between Hendersick, Trelawne, and Pelynt.

DARTMOUTH SLATES.

In following the coast from Cawsand to Polperro all the typical varieties of the Dartmouth slates are encountered. The characteristic pinkish, magenta or purple and green variegation is met with in all its variations, the most vivid colouring being perhaps present in the cliffs of Talland Bay and its vicinity, where deep purple or indian-red and green tints prevail, practically identical with those locally exhibited by the variegated Upper Devonian slates of Mutley and other places in this map.

This typical variegation is however very far from being constant; greenish tints are often prevalent, as near Sharrow Point. Greenish-grey, pale buff, and pale-red and grey locally prevail. In many of the inland quarries and exposures only pale-red and greyish, brownish, or buff, tints which have no distinctive aspect are to be seen, as in South Devon. The local absence of distinctive colouring renders the boundaries between this series and the rocks of the Meadfoot group very uncertain, in places, west of Millbrook. In composition the Dartmouth slate series is by no means homogeneous. Besides the hard, glossy, and partly siliceous slates which are so characteristic of the group, cleaved mudstones or slates of a more distinctly argillaceous type are common, and the siliceous materials vary from fine laminated siltstones, and hard fine grits, or quartzite beds to rough grits and distinctly arenaceous beds.

Owing to faulted junctions and the doubt attaching to boundaries mainly drawn on colour distinction, one cannot assign any definite stratigraphical value to the relative prevalence of beds of grit or quartzite in parts of the coast section. If the rocks were less disturbed it is doubtful if we should find any definite general sequence in the distribution of the different materials.

On Withnoe Common, for instance, reddish, magenta, grey and greenish variegated slates contain bands of fine grit which coalesce to form masses of fine quartz-veined grit or quartzite. A dyke-like ridge of quartz rock in the vicinity may be thus accounted for. By the military road on Withnoe Cliff massive beds of quartzite and quartz with a slaty jointing rest on gnarled grit-shales. If not due to an overthrust, the gnarling would here perhaps be due to unequal strain, and indicate a tendency to cleavage which is shown by jointing in the massive rock.

In the coast between Penlee Point and Rame Head intercalations of hard grit are rendered very conspicuous by quartz veining and partial replacement. Here the grey colours are suggestive of a syncline of beds in the Meadfoot group, but variegated slates have been seen on the east and west. Within the (partly faulted) boundary assigned to the Dartmouth slates on the east side of the Portwrinkle fault, as already stated, the lower beds of the Meadfoot group seem to be well represented.

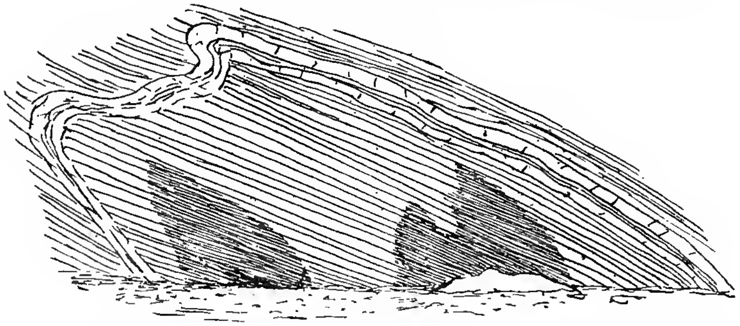
At the margin of the map west of Polperro dark slates and grits have been included in the Meadfoot group, and also on the east side of the fault in Portnadler Bay, between Hannafore Point and the Looe Estuary, and between Millendreath Beach and Colmer Rocks. Although *Pteraspis* occurs in the dark slates in the last two instances, no boundary could be drawn in them so as to include them in the Dartmouth slates. Between Millbrook and Withnoe the boundary is similarly placed between dark grey rocks and more or less variegated rocks. It will therefore be seen that within certain limits the boundary between these groups cannot be consistently drawn.

In the Dartmouth slates the distinction between cleavage and bedding is often extremely obscure; this is partly due to an approximate coincidence between the planes through isoclinal plications accompanied by thrusts, or to similarly displaced sharp inverted folds. The presence of hard grits here, however, as on the Revelstoke coast brings out the contorted bedding in so many places as to leave no doubt of the repetition of the slates by contortion to a much greater extent than is apparent to the eye. Contortions rendered manifest by hard grit beds are especially numerous in the dark slates taken as basement beds of the Meadfoot group. West of Polperro vertically contorted or zigzagged bedding is well marked.

In the variegated slates contorted grit beds are to be seen north of Rame Coastguard Station (Wiggle Cliff), in many places between Portwrinkle and Downderry (especially near Coldeadon Point on the 6-inch map), in several places between Seaton Beach and Colmer Rocks, and in the Talland and Polperro coast. Intercalations of compact grit or quartzite beds with distinctly cleaved purple, greenish, and buff slates are well shown in the cliff and beach reefs on the west side of Seaton Beach. Numerous fish remains are to be seen in the lower part of the lowest grit bed in the cliff. Near this the directions of cleavage dips are south by east and the bedding dips east, or east by south.

At about 990 yards west of Seaton Beach quartzite or hard grit beds intercalated in greenish buff-weathered slates appear to form an anticline overarching greenish and greenish-grey slates, which pass irregularly downward into magneta slates, the darker patches shown in the sketch, Fig. 1. Here the distribution of the colours as an indication of bedding is shown to be quite unreliable, but this is not always the case. South of Portnadler Bay on the north of the Hore Stone the cliffs consist of banded indian-red and green slates with beds

FIG. 1.—*Variegation in cliff, 990 yards west of Seaton Beach.*



of hard grit, the cleavage has a northerly dip of from 50° to 60°, and the bedding, shown by the colour banding as well as by the grit beds, gives northerly dips of 70° to 80°. In variegated slates of the Upper Devonian by the estuary of the River Plym (Laira) contorted bedding is shown by colour banding of a similar type. Where grit-shales are developed in the Dartmouth slates, as at Sharrow Point, cleavage may be absent. These beds suggest an anticlinal structure at Sharrow Point, where they are gnarled together with occasional quartz bed-veins. The gnarling here seems to denote resistance to cleavage.

Purple mottled slates of the Mothecombe[1] type occur between Sharrow Point and the outcrop of the rocks of the Meadfoot group toward Tregantle. In a quarry in Whiterocks Plantation, 200 yards south of Cawsand, greenish and grey argillaceous slates with grit give a northerly cleavage dip of 60°, the bedding dip being apparently north at 80°. Some decomposed material is present which may denote residue of calcareous organisms or the presence of fine tuff.

Brown friable material is occasionally present in the Dartmouth slates in the form of irregular patches or nodules; these suggest the decomposition of calcareous matter probably of organic origin, as here and there pale reddish limestone patches have been met with, occurring in a similar manner and, rarely, containing sections of small univalves, probably *Bellerophon*.

Furthermore the decomposition of fish remains leaves dark brown residues in places, and where these are present in grit beds the hard close-textured rock becomes more or less friable. The honey-comb layers are more frequently seen than the harder striated surface sculpture of *Pteraspis*.

Although no protracted search for specimens could be made when mapping this coast, fish remains were noticed in many places, and small calcareous patches or decomposed residues met with here and there. The following list of localities, more or less promising, may be of use to those who have the time at their disposal for protracted search.

On the east side of Rame Head at Bull Cove the rocks contain brown friable material which seems to be of organic origin. Toward Long Sands, at three-quarters of a mile from Rame Coastguard Station, grits partly dark brown and friable occur, also on the south of Wiggle Cliff. Reddish limestone lenticles with *Bellerophon trilobatus* J. de C. Sow.[2] are visible near the commencement of Trewinnow Cliff, a mile and an eighth from the Coastguard Station and at the commencement of Tregenhawke Cliff a quarter of a mile further on.

At about 300 yards from this traces of *Pteraspis* (?) were noticed, and in grits about 260 yards further, south of the Withnoe felsite; about here the cleavage dips are higher than the bedding, which gives south-south-easterly and south-easterly inclinations often of not more than 20° to 25°.

Within half a mile from the Portwrinkle fault numerous traces of fish remains were observed in several places, chiefly in grey beds.

In the beach reefs at Portwrinkle hard quartzite beds interbedded in the variegated slates are in places so full of fish remains (honey-comb layers of *Pteraspis*) that they assume the aspect of dark brown tough friable grits. These rocks are similar to those near Wiggle Cliff. They strike north-west and south-east, probably an abnormal deflection due to proximity to the Portwrinkle fault, as the strike bends sharply in a south-westerly direction almost at a right angle at the point about 290 yards west of Portwrinkle.

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[1] At the mouth of the River Erme in South Devon.

[2] Identified by Mr. E. T. Newton.

At half a mile further west there is another abrupt change in strike from south-west in the beach reefs to north-west in the cliffs, with respective dips to south-east and north-east.

Near Downderry there are signs of fish remains and of crushed friable organic material in the slates and grits.

Between Seaton Beach and Downderry numerous obscure fish remains were noticed in beach reefs of dull green-grey and purple mottled slates, with hard quartzite beds in part slaty, striking nearly north and south but changing to a north-east strike toward the cliffs.

Numerous fish remains are to be found in the lower part of an intercalated quartzite bed in the variegated slates on the west of Seaton Beach already referred to. The variegated slates in the beach reefs here contain reddish irregular calcareous nodules, evidently of organic origin and suggestive of *Bellerophon*. Between 300 and 500 yards west of Seaton Beach there are numerous traces of fish remains, and calcareous nodular patches are also met with. The latter are also present at about half a mile from Seaton Beach near the section figured (Fig. 1). There are veins in places on this coast resembling quartz-albite.

Toward the outcrop of the Meatfoot group the section is much obscured by slips and talus. Fish remains are to be found in the dark slates near a small mass of diabase on the coast south of Bodigga, and at about 240 yards to the west a very acute local deflection of strike is visible.

For 260 yards south from Looe harbour the reefs consist of grey slates with hackly grits and hard dark slates, mottled with bright red splotches in places, intercalated with hard grit or quartzite beds, and with bands of Pteraspidean remains in one or two places. These are succeeded by buff and green beds which quickly give place to variegated grey, purple, green and buff slates with beds of quartzite and fish remains in the reefs north of Hannafore Point, in the cliff 80 yards south of Monk's House, and near their junction with the dark slates in Portnadler Bay, in which also fish remains occur.

The variegated slates of Looe Island, with occasional intercalations of quartzite, contain fish remains, especially on the north, north-east, and north-west coast. In one place, near the northernmost house on the Island, fish remains were found in slates, bedding being shown by slaty grit to cross cleavage at a low angle. The schistosity dips on Looe Island are south to south-south-east.

Traces of fish remains were noticed in the variegated slates on the south side of the Portnadler fault. In Talland Bay the honey-comb layers and other Pteraspidean remains are to be found. On the west coast at about 100 yards south of Talland Sand limestone pellets and nodules occur in magenta slate, and fish remains are recognizable in the variegated slates and grits. Green igneous rock is visible in the cliff here. At 100 to 150 yards to the south contorted grey slates with distorted siliceous lenticles and grit-shales may denote synclines of, or pass into, the variegated beds. At about 100 yards further south friable nodules or patches are present in magenta slates (Lakerock, where calcareous nodules were noticed by Peach)[1].

R. Q. Couch[2] records the discovery of *Bellerophon* in Talland Bay, and of the extension of fish remains up the cliffs of the Polperro coast. At Giggan Cove, about a quarter of a mile west of the entrance to Polperro Harbour, Peach noted greyish limestone, several feet wide, containing fish remains and *Bellerophon*, and an extensive fault; he considered this the same horizon as at Lakerock, and that it was prolonged to the east shore of Talland Bay (Rotterdam Cliff). The fault mentioned is probably prolonged to Talland Bay as a south-westerly dislocation traverses the beach reefs there.

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[1] *Trans. Roy. Geol Soc. Corn.*, vol. vi., p. 79.

[2] *Ibid.*, p. 147

The grey and buff quartzites of Bin Down and of Corgorlon Tor contain fish remains, and the very irregular occurrence of the variegated beds may be due to impersistence of variegation and to weathering, but as this cannot be proved the Dartmouth slates have been restricted to the limits shown on the map in this anticline.

Mention has been made of the occurrence of grits near traces of variegated slate on the south of Muchlarnick; here also there is a probability of Dartmouth slates being represented to an appreciable extent.

The Pengelly collection, presented to the Jermyn Street Museum by Mrs. Pengelly, includes many fine specimens of fish remains from the rocks of the south-east coast of Cornwall, from Rame Head to Polperro. The localities and numbers proceeding along the coast westward are as follows:—

Rame Head, in grey slate, 7 specimens, numbered, 5685, 5695, 5710, 5725, 5730, 5732, 5737.

Whitesand Bay, in grey slate, 2 large specimens, numbered, 3684, 3692.

Limmicks, Looe [Foreshore reefs of dark slate and grit beds, about a quarter of a mile north-east of East Looe beach, 1 specimen, numbered, 5701.

Wallace, Looe [locality not known], 6 specimens, numbered, 5696, 5699, 5704, 5722, 5723, 5746.

Looe, 1 specimen, numbered, 5705.

Near Looe, 4 specimens, numbered, 5712, 5714, 5733, 5745.

Ree Point, Looe, 1 specimen, numbered, 5727.

Needles Eye, Looe, [? Neilsea, on foreshore south of Looe Harbour, on 6-inch map], 10 specimens, numbered, 5686, 5702, 5703, 5704, 5708, 5709, 5713, 5720, 5721, 5722.

Old Mills, Looe, 4 specimens, numbered, 5682, 5693, 5700, 5707.

Looe Island, 5 specimens, numbered, 5687, 5688, 5717, 5719, 5729.

Talland Sands, 2 specimens, numbered, 5738, 5739.

Polperro, 3 specimens, numbered, 5734, 5740, 5741.

None of the above are in a red or variegated slate matrix.

Dr. A. Smith Woodward[1] described a cornu of *Cephalaspis carteri* (McCoy), found by Mr. Upfield Green near the Old Mill at Looe. The locality appears to be at or near the junction of the variegated slates, south of Hannafore Point, with the dark slates of Portnadler Bay. The specimen was associated with remains of *Pteraspis cornubica* (McCoy). The only other species of *Cephalaspis* with large marginal tubercles hitherto found seems to be *C. pagei* (Lank.), from the Lower Old Red of Forfarshire.

Finely ribbed Pteraspidean fish plates from South Cornwall "sometimes received the name of *Scaphaspis*,[2] which now proves to be applicable to the ventral shield of any member of the family." Dr. Smith Woodward further remarks that in Western Europe *Pteraspis* is characteristic only of the Lower Devonian or Lower Old Red Sandstone not descending below the base of that formation, where it is preceded by a simple shield *Cyathaspis*.[1]

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xii., p. 431.

[2] H. Woodward and E. Ray Lankester. *Geol. Mag.*, vol. v., 1868, p. 248.

The occurrence of *Bellerophon trilobatus* J. de C. Sow., in the Dartmouth slates of this coast has been long known, and from the observations of material distributed in the slates here and there along the coast, similar to that in which its presence has been proved, it may be regarded as a common fossil. For its occurrence in higher beds in the Lower Devonian in the Torquay area and elsewhere see 'Memoir on Geology of the Country Around Torquay,' p. 25, footnote, and p. 35.

MEADFOOT GROUP.

Although the rocks of this group occupy a very small part of the coast as compared with the Dartmouth slates, inland they cover a larger area which is broken by the Portwrinkle fault into the Looe district and the Tregantle district; each of these districts is cut up by faults so that an unbroken succession of the components of the group is nowhere to be found.

A south-westerly strike brings the basement dark grey slates with hard grit and quartzite-beds and siliceous interlaminations from the coast south of Bodigga, along the seaward rock reefs of the East Looe coast to Looe Harbour mouth, and thence to Hendersick and Portnadler Bay where they are cut off by the fault. From Bodigga they follow the same strike along a narrow outcrop, probably attenuated by fault, between fossiliferous beds with grits and the Dartmouth slates for a mile inland. From this point east they are probably cut out by a faulted boundary of the Dartmouth slates, but come in again and, crossing the Seaton Valley at Keveral Wood, run round the irregular boundary of the Dartmouth slates on the south of Treyone and Minard Chapel to the Portwrinkle fault which brings them in contact with Eifelian slates.

These basement rocks surround the small Dartmouth slate anticline south of Bake Wood. Their outcrop on the south side of it is narrowed by a faulted junction with the fossiliferous beds. The southerly termination of the Dartmouth slates in Lydcott Wood appears to be a fault crossing the Seaton Valley, and thence up to the Portwrinkle fault separating a strip of basement beds on the north from Dartmouth slates on the south. From Lydcott Wood this dislocation appears to run in a west-south-west direction, marked by springs here and there between Tredinnick (near Hessenford) and No Man's Land, till it meets the south-south-east cross fault that shifts the Dartmouth slate anticline between Bray and Corgorlon. The grey slates, grits, and quartzites evidenced by exposures or boulders in the clayey ground on the north of this fault belong to the basement beds, and also the rocks on the higher ground between Lydcott Wood and Bin

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[1] A. Smith Woodward. *Trans. Roy. Geol. Soc. Corn.*, vol. xii., p. 229.

Down in all probability. The same series bounds the Dartmouth slates at Corgorlon, and to the west of the East Looe Valley extends through Treworgey, Tredinnick (near Duloe), and Muchlarnick toward Pelynt.

So far we have been following the outcrop of the basement beds of the Meadfoot group on the south of the Bin Down and Corgorlon anticline and south of the faulted continuation of its strike.

On the north of the Corgorlon inlier, as mentioned in the preliminary notes, the Dartmouth slates are faulted against fossiliferous beds near Plashford and from thence to Wringworthy, where the anticline is shifted by a cross fault. On the north border of the Dartmouth slates between Wringworthy and the Portwrinkle fault, although there are dark slates which might be referred to the basement beds, in the Seaton Valley and elsewhere, there is no certain proof of their occurrence, and south of Catchfrench the Dartmouth slates seem to be bounded by fossiliferous Meadfoot beds, at the Portwrinkle fault. Taken in connection with the very partial and imperfect representation of the Looe fossiliferous rocks on this side of the anticline it seems probable that, if represented, the basement beds are local and bounded by a fault or thrust.

The difficulty experienced here is similar to that on the west of the East Looe Valley, namely, the general similarity of the upper and lower parts of the Meadfoot group.

In the preceding notes the term basement beds is applied to the part of the Meadfoot group which underlies fossiliferous beds and overlies the Dartmouth slates. This, however, is a relative term, as no definite base can be traced for the fossiliferous beds, nor can their upward extension be definitely determined owing to the impersistence of lithological types and to the impersistence of fossiliferous horizons in an area of contorted rocks where faults are numerous and difficult to detect. Moreover, through decalcification grits and slates originally more or less calcareous now present the aspect of more or less arenaceous grits and slates.

The masses of grit at Kilminorth, Portlooe, East Looe, and Bucklawren, being for the most part well defined by lithological characters, were mapped, and other occurrences of a somewhat similar character were also separated; but these are misleading, as their impersistence in most cases is no doubt due to changes in character and colouring, rendering their further separation from the slates and shales with which they are associated impossible.

The coast section from Millendreath Beach to Looe gives an inverted upward succession. The slates with hard grit or quartzites, sometimes in masses and intensely contorted in stacks on the beach reefs, are succeeded by grey slates and interlaminated calcareous shales with lenticular masses of dark grey limestone crowded with irregular patches of white carbonate, perhaps of monticuliporoid coralline origin. These beds form the promontory at the east side of Millendreath

Beach and Raven Rock; in the higher part of the cliff they weather greenish buff. They rest on even, red, buff, and grey shales and shaly grits with much decomposed brown fossiliferous friable material containing distorted impressions of large brachiopods, *Pleurodictyum problematicum* (?), &c., on brittle reddish quartzose grits, well shown at Plaidy Beach, the 'Pleida' of Peach.

Peach [1] here records the discovery of *Crinoids, Turbinoliæ, Orthoceratites, Productæ, Spiriferæ*, &c., in arenaceous very fossiliferous friable schist. Purple, yellow, and grey mottled igneous rock occurs in the section.

Between Plaidy Beach and the next exposure of these beds near East Looe (Gun's Hill) the rocks are dark grey slates with igneous rock in several places, some limestone with zaphrentid corals near Chough Rock, and interlaminated calcareous beds coming on toward Looe. A large *Spirifer* was obtained (at about 700 yards from Millendreath Beach), and crinoids are, as Peach noted, abundant. The igneous rocks resemble those of the Torcross section, and are displaced by faults.

At Gun's Hill, about 200 yards from Looe Pier, grey interlaminated calcareous shales with bright red bands and veins and patches of monticuliporoid limestone overlie (invertedly) pale pinkish brown quartzose grits (hard and brittle), containing *Pleurodictyum problematicum*, with lenticular patches of red limestone with calc spar, patches similar to those in the grey beds. The grits have red ferruginous specks and glistening greenish yellow shaly flakes; they contain numerous impressions and casts of fossils. They are probably brought on by a faulted inverted syncline. Peach records numerous crinoids, large shell impressions, *Turbinoliæ, Favosites, Fenestellæ*, &c., in light coloured, occasionally red, quartzose grit and, in hard quartz-veined red rock, crinoids, corals, *Terebratulites*, &c. The grit rocks cannot be traced from Gun's Hill to Plaidy Beach. There are buff and drab slates or shales in the intervening distance associated with arenaceous material which may represent them, and there are similar signs of the deterioration of well-marked fossiliferous grits, &c., toward St. Martin, and toward the western end of the Kilminorth mass. Arenaceous beds or arenaceous and argillaceous shales may represent these gritty developments at, and east of, Pelynt.

The Plaidy Beach grits are continuous to Bucklawren, and the same series runs from Bucklawren toward Trenant Wood, whence they continue to Trelawne and Barcelona.

From Sandplace and Morval to Looe and Bucklawren the fossiliferous grits and argillaceous and arenaceous equivalents (?) are well represented. Between Bucklawren, Hessenford, and the Portwrinkle fault, although the grits can seldom be separated out, the persistence of the fossiliferous series as a whole has been proved by many observations, and grits, analagous to those of East Looe and Plaidy Beach, occur near

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. vi., p. 19.

Hessenford and near the Portwrinkle fault on the north side of Perdredda Wood, also amongst arenaceous and argillaceous rocks near Treyone.

Opposite Looe Station reddish crystalline limestone occurs in a small mass overlying slates with fine tuffs. A wall conceals their relation to slaty grits on the south. At the Globe Inn brown decomposed shaly beds, with hard blue limestone lenticles, were seen. Near Looe Station the railway cutting shows calcareous slates or shales, much decomposed friable material, more or less lenticular beds of crinoidal limestone, and grey and drab weathered, locally red-splotched, slates and grey and brown slaty calcareous grits, with hackly fracture. Near the Gas Works further north red and purple fine slaty grits, slates, and red-speckled quartzose grits, with fossils, come on. A quarry behind the Gas Works yielded the following species, determined by Mr. E. T. Newton:—

Orthotetes hipparionyx *Vanux.*
Spirifer.
Streptorhynchus.
Pleurodictyum problematicum *Goldf.*

For a quarter of a mile to the north the rocks chiefly consist of very fossiliferous slates or shaly beds occasionally with limestone but more often with decomposed friable bands. The following were obtained by the railway north of the Gas Works;—

Spirifer primævus *Stein.*
Sp. young primævus (?)
Pleurodictyum problematicum *Goldf.*

A buff rock, apparently a tuff similar to that opposite Looe Station, was noticed on the south side of the fish ponds at a mile north of East Looe.

At about half a mile from this, up the tributary valley toward Morval, there is a quarry ("At Steps") where Peach obtained crinoids in friable arenaceous stone seams between beds quarried for economic purposes. The slates here contain compact and rough grit. On the hill above the quarry near Stepshill Wood a *Spirifer* resembling a young specimen of *Sp. primævus* Stein., was obtained. The compact grits resemble the pale reddish brown grit of Looe, but they are only occasionally met with amongst the grey slates with decomposed calcareous matter and slaty brown-weathered grits and yellow and buff arenaceous rocks developed south of Corgorlon.

Limestone occurs in the slates opposite Sandplace on the west bank of the East Looe; at about half a mile south of Sandplace by the high road in a quarry exposing igneous rock; near the entrance to Trenant, and on either side of the river at a quarter of a mile further south. At 1,150 yards due east of Morval Church limestone is visible in a small slate quarry on the east of the cross fault often referred to.

To return to the rocks north of Looe Station, the slates with limestone here and there are exposed by the road which forks to the right leading to St. Martin, and behind a new house hard quartzose grits and grey partly calcareous slates. This is the new road cutting in Common Wood referred to by Peach, as exposing many beds of limestone and similar rocks to those of Portlooe with *Cyathocrinus* and a greater quantity of bivalves.

On the east side of the Millendreath Valley, west of Bucklawren, fossiliferous grit stones contain crinoids, a fossil like *Poteriocrinus*, *Spirifer*, and *Pleurodictyum problematicum* Goldf. On the opposite side of the valley east of the school there is a quarry in tough arenaceous slates or shales breaking into rough irregular slabs and associated with some brown weathered grits containing small crinoid ossicles and impressions suggestive of *Chonetes*.

Between Longcoe and Hessenford, and Bucklawren and the Seaton Valley, the rocks present similar types and structures to those in the grey Meadfoot beds of Torquay, and signs of fossils are met with here and there throughout. Near Longcoe, north of the school, signs of brachiopods are met with in tough brownish grits associated with buff and drab arenaceous slates. The large farm by the road to Trelowia half a mile to the east of No Man's Land is called Lower Treveria, and the smaller farm west of it Higher Treveria; fossiliferous grits occur in grey slates near the latter, and in a quarry by the stream north of Lower Treveria fossiliferous slates are exposed.

Between the confluent streams further east irregular slaty limestone was noticed in the wood near the path to Tredinnick.

At three-quarters of a mile north-west of Bucklawren there are fossiliferous slates, shales, and grits.

On the margin of Keveral Wood, over a mile due east of Bucklawren, irregular grey gritty slates with brown decomposed material are exposed, with south-easterly dips, in a quarry; near this there is surface evidence of a patch of reddish grits and of fossils resembling *Chonetes*. The strike of these horizons carries them across the Seaton Valley in the direction of Treyone. Up stream to within half a mile of Hessenford we get exposures of slaty calcareous grits and slates with limestone, recalling beds at Noss Point by the Dart and elsewhere. If these beds were exposed on a coast line they would present the same series as that so well shown on the Tregantle coast. East of Trelowia distorted fossils occur in them, and elsewhere.

Toward Hessenford reddish and grey quartzose grits of Looe type come on; they are probably shifted or bounded on the east by a north-easterly fault. West of Hessenford by the turning to Trelowia slaty calcareous grits of a characteristic Meadfoot type are exposed with a low westerly dip.

At half a mile west of Hessenford a quarry exposes similar siliceo-calcareous slates with numerous decomposed distorted fossils. The cleavage dip is south-east, and the rocks are intersected by a fault.

East of Hessenford, at 660 yards from Bake in a direction

S. 10° W., brownish sandy slates and brown grit have been quarried. From the numerous distorted casts and impressions of fossils they contain the rocks must have been largely decalcified. Amongst the fossils obtained, Mr. E. T. Newton was only able to determine one specifically, viz., *Streptorhynchus gigas* (McCoy), *Orthis* and probably *Strophomena* also occur. Friable fossiliferous films occur in the slates near Minard and between Minard and the Portwrinkle fault (in a quarry by the lane and on the north side of Perdredda Wood) the slates or shales contain fossiliferous friable bands with numerous distorted brachiopods, and are similar to those in the quarry near Polyne, between Hendersick and Barcelona. West of Minard small fossils, chiefly crinoids, occur in brown gritty rock.

Having now traced the fossiliferous rocks from the East Looe valley eastward to the Portwrinkle fault, we have to trace them from Looe westward. From West Looe westward the rocks are more or less red in colour, and contain quartzose red-speckled grit. If their boundaries have any stratigraphical value, as very fossiliferous grey rocks occur on the north side of the Portnadler fault and are not represented south of Portlooe where the dark slates bounding the red rocks seem to be below the fossiliferous horizons, most of their southern boundary must be a fault, joining the Portnadler fault near Hendersick.

Mr. Upfield Green has recorded the following fossils from a quarry in West Looe (south side): *Orthotetes hipparionyx* (*O. personata*), *Spirifer primævus*, *Sp.* sp. (cf. *macropterus*), *Streptorhynchus gigas*, *Pleurodictyum problematicum.*

A small quarry at half a mile west of Portlooe exhibits purplish red-speckled quartzose grits and fine grained grit with straw-coloured flakes or small sheared patches. They contain small fossils, chiefly crinoids, and are either faulted or folded.

Peach compares the friable arenaceous rocks with fossils in the road cuttings between here and West Looe to those of the East Looe cliffs; near Portlooe he recorded a fossil resembling *Nucula*, *Terebratulæ*, and crinoids in hard grey speckled rock, and in quarries in hard red quartzose rocks at the head of the (then) new road to Looe, bivalves *Terebratulæ*, *Cyathocrinus*.

Very fossiliferous brown rock probably containing *Orthotetes hipparionyx* was exposed by the road to Talland on the east side of Hendersick. At half a mile from this very fossiliferous grey grits and shales with arenaceous films are exposed near the Portnadler fault and south-west of Tencreek, the large farm not named on the map. Besides zaphrentid corals, *Orthotetes hipparionyx* (Vanux), *Spirifer primævus* Stein., and *Pleurodictyum problematicum* Goldf., identified by Mr. E. T. Newton, were obtained.

Polyne is the farm shown, but not named, on the map, 300 yards south-east of the Roman Catholic chapel. North of Polyne and east of the Roman Catholic chapel there is a quarry in grey shales with intercalated brownish friable fossiliferous bands dipping north. From this quarry Mr. Upfield Green obtained *Athyris*, sp., *Orthotetes hipparionyx* (= *Orthis personata*), *Rhynchonella pengellyana* (?), *Spirifer* sp., *Streptorhynchus* (cf. *umbraculum*) presented to the Jermyn Street Museum, and a fossil figured and named by him *Nereitopsis cornubicus*.[1]

Since this manuscript was compiled the results of further search in the same quarry has appeared.[2] The following being the complete list;—

- Fenestella.
- Pachypora.
- Petraia pauciradiata (*Phill.*)
- P. celtica (*Lam.*)
- P. radiata *Münst.*
- P. punctatocrenulata *Röm.*
- P. gigas *McCoy.*
- Pleurodictyum problematicum *Goldf.*
- Lodanella mira *Kayser.*
- Nereitopsis.
- Phacops ferdinandi *Kayser.*
- Strophodonta gigas *McCoy.*
- Streptorhynchus.
- Athyris cf. undata *Defr.*
- Rhynchonella.
- Rensellæria.
- Orthis personata *Zeill.*
- O. vulvaria *Schl.*
- O. circularis *Sow.*
- Spirifer primævus *Stein.*
- Sp. subcuspidatus *Schnur.*
- Sp. cf. hystericus *Schl.*
- Crinoid columns (some ¾ inch across).

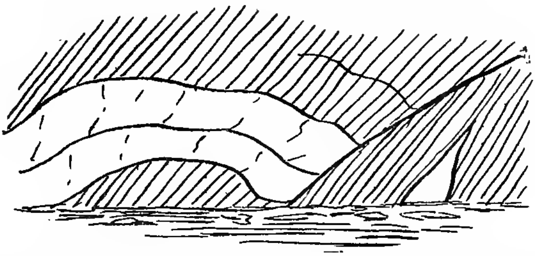
Similar shales, interlaminated with decomposed fossiliferous matter, occur north of the Looe Gas Works and at Millendreath, where they are peroxidated.

Between Polyne Quarry and the Reservoir, very fossiliferous brown slaty rocks and hard grey grits with crinoids are exposed in a quarry in the valley, which may be seen from the high road to Looe.

At the Reservoir there is a quarry in hard shales interleaved with brown friable fossiliferous material with zaphrentid corals and numerous traces of brachiopods.

In Trenant Wood hard grits, often reddish, associated with slates and slaty grits, contain crinoids and brachiopods, and are brecciated with glistening shaly flakes. These beds are repeated by numerous folds, together with grey slates with occasional limestone bands and much brown friable material, which probably underlie them. Near the point opposite Looe

FIG. 2.—*Section opposite Looe Station.*



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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xii, p. 227.
[2] *Geol. Mag.*, Jan., 1906, pp. 34, 35.

Station the hard grits and slates are faulted or thrust (Fig. 2) against brown shaly fossiliferous grit and grey slates with red mottling and sheared buff decomposed igneous rock.

In Kilminorth Wood the same series is continued by yellowish-buff and red shales, grits, and slates, and more or less calcareous grey slates and shales with igneous rock and limestone in places. A greyish fossiliferous grit in Kilminorth Wood contains crinoids and a small *Pleurodictyum.*

A quarry near Kilminorth exhibits buff shaly arenaceous rocks, and from thence westward hard grits are less plentiful. At Barcelona yellow and pale buff slaty arenaceous rocks give a northerly cleavage dip of about 45°; the bedding may dip north at 25°.

In Barcelona Quarry Peach obtained ill-defined encrinites in brownish red rock with a great quantity of quartz.[1]

Jonathan Couch[2] described the Barcelona Quarry (at Trelawny) rock as pale yellow stone separating into thick slabs, useful for building as it bears dressing, dipping north, and worked to over 40 feet from the surface. He considered the crinoidal remains obtained as similar to those found at Tremayne, west of Pelynt Church. Mr. Collins gives Trelawne (Trelawny according to Couch), as the locality for *Petraia trelawniensis*, and *Cyathocrinus annulatus.*

From here to Pelynt argillaceous and fine arenaceous rocks seem to prevail; there are few exposures, and apparently very few signs of fossils or of calcareous beds.

On the north of Trelawne by the road to Kiln Wood there are fossils in the slates. Calcareous slates and sheared igneous rocks are exposed here and there by the West Looe up to Sowden's Bridge, and for some distance further north friable material occasionally fossiliferous has been detected in the slates; but the slates, slaty grits, hard grits, and arenaceous materials, which occur on the north of Trenant Park give no indication of a definite fossiliferous series, although they are no doubt in part unpromising representatives of it.

On the north of the Dartmouth slate anticline and of the faults which form its westerly continuation, reddish grits of the Looe type only occur at Wringworthy on a fault line. The rocks are grey slates sometimes argillaceous, with occasional beds, bands, or seams of compact grit. At Plashford they are fossiliferous and contain some limestone.

About 200 yards north of Plashford on the west side of the East Looe river crinoidal limestone occurs in thin papery shales, and there are signs of calcareous slates at about half a mile further north. At about half a mile east of the Plough Inn, Duloe, there are signs of crushed brachiopods in the slates.

By the road from Bin Down to Liskeard decomposed fossiliferous material is intercalated in the slates in places, almost up to the Staddon grit boundary. Crushed fossils are to be seen in it near Polgover.[1] A quarter of a mile south of Polgover partly calcareous slates dipping south-south-east at 33° are exposed in an old quarry. South of Lower Trenode hard blue-grey irregular slaty grit containing crinoid joints and brown fossil traces crops out not far north of the variegated Dartmouth slates.

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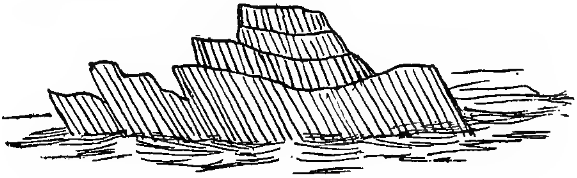
[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xi., pp. 421 and 559.

[2] *Ibid.*, vol. vii., p. 249.

In the Seaton valley the Dartmouth slates are bounded by dark-grey slates which might belong to the basement beds of the Meadfoot group. About 300 yards north of the junction on the eastern slope slaty, partly calcareous, fossiliferous rocks with hard grit were noticed. South of Catchfrench, at a quarter of a mile east of Bonialva, the Dartmouth slates seem to be bounded by similar fossiliferous slaty grit. From this evidence there can be very little doubt that a considerable part of the Meadfoot group is cut out by fault, or thrust, on the north of the Dartmouth slate anticline.

We have now to consider the smaller area occupied by the rocks of the Meadfoot group between the Portwrinkle and Cawsand faults, commencing with the coast section. At about a quarter of a mile from Sharrow Point in Crowstone Cliffs the variegated Dartmouth slates give place to grey rocks; there is a fault which may affect the junction. On one side of it dark slates with hard quartz-veined grits occur; on the other, reddish and grey slates with hard grits. At any rate, rocks of Dartmouth slate type do not reappear until we approach Portwrinkle, and from here to the Tregantle valley the rocks are comparable to those forming the seaward reefs on the East Looe and Millendreath coast.

FIG. 3.—*Cleavage and bedding,* 640 *yards west of Sharrow Point*



At about 640 yards from Sharrow Point cleaved grits exhibit a gentle syncline in a beach reef, the cleavage dip being south-east at 55° (Fig. 3). At about 100 yards from this a sharp inverted anticline is shown in a reef of hard grits. Slates, slaty grits, and hard grey grit beds, generally dipping south-east but much contorted in places, are seen for the next 200 yards. The grey colour here gives place to red, introducing a series of shaly calcareous and siliceous rocks with seams of crinoidal limestone at the Tregantle valley where the red colour locally gives place to grey, brown, or yellow. The dips are easterly at 35° and 45°.

We then successively encounter buff and yellow shales and soft sandstones with hard irregular ferruginous bands (pan) for 100 yards, a colour change from yellow to red for 10 yards, buff and red sandy slates or shales with brown ferruginous mottling for 50 yards, 5 feet of red and bluish limestone with numerous crushed and distorted fossils (monticuliporoid corals ?, &c.), bluish sandy shales mostly buff through weathering for 24 yards.

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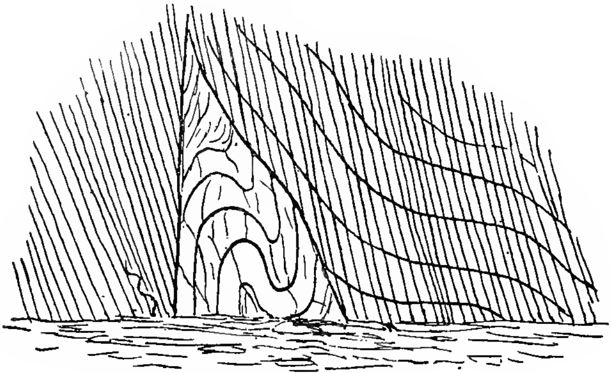
[1] Giles (*Trans. Roy. Geol. Soc. Corn.*, vol. vii., p. 99) compares dark brown fossiliferous beds at Polgover Cross with decomposed beds at Looe, and suggests the inclusion of the Bin Down quartz rocks in the fish bed series.

Up to this the apparent dip is uniform, at about 33° east by south, but here it changes to 45° and there are signs of a sharp inverted anticline, and of contorted quartz (? bed) veins. Fossiliferous limestone occurs in the buff rocks which continue to the strip of Head south of Blarrick, with indications of bedding at 15° crossing cleavage planes with a dip of 50°. The general direction of dip is always easterly between east and south-east unless stated to the contrary. Under the Head grey and buff slates with lenticles and lenticular masses of limestone give (cleavage ?) dips of 45°. A path here ascends the cliff and brittle grits crop out; a decomposed mass of igneous rock is visible under the Head. There may be a fault here, bringing on deep red slates, a siliceo-calcareous series containing limestone and many crushed fossils, with cleavage dips of 40° increasing to 60°, traversed by indications of bedding with a dip of 10° increasing to 35°. The red colour gives place to grey and buff here and there. These beds give place to pink, whitish and red, distinctly bedded, arenaceous rocks with ferruginous concretions and beds of hard brittle, quartzose or compact, grit with dips of from 20° to 30°. There are indications of a fault at about 100 yards from the Head, and at about 200 yards further on the grits seem to rest on red, grey and buff slates, mostly siliceous, more or less calcareous, and with beds or lenticles of limestone. Dips of 20° to 25° traverse cleavage planes dipping at from 60° to 65°.

Toward their faulted termination at Black Ball Cliff about a mile from Portwrinkle, the direction of dip changes from east by south to south-south-east. A small mass of yellow-weathered igneous rock occurs at the fault (Fig. 4) which separates the calcareous slates from contorted grits in part slaty and with brachiopods. The grits are apparently faulted against dark slates with gnarled signs of contorted bedding, evidently belonging to the basement beds of the Meadfoot group. Near this, greenish and purplish tints suggest the presence of Dartmouth slates, and they are also present near Crafthole, but otherwise from Black Ball fault to Portwinkle fault the rocks consist of dark grey slates with beds of hard grit and siliceous interbanding, and may be included in the basement beds.

FIG. 4.—*Black Ball Cliff, 1 mile east of Portwrinkle.*



This coast line, through low easterly dips, presents the appearance of a great thickness of largely decalcified fossiliferous rocks outcropping in regular succession; the arenaceous and calcareous beds have their exact equivalents in the coast section south of Staddon (in Sheet 349). We find in them also repeated resemblances to the rocks of Ringmore type in the Kingsbridge and Salcombe area, and in the section from

Scabbacombe Head northward toward Brixham, as well as representatives of the Looe fossiliferous horizons. But in none of these areas is there so great and apparently continuous a development of fossiliferous beds.

This is probably due to the reduplication of the strata by fault south of Blarrick, where the cliff is capped by Head, and to repeating curves which cannot be detected through absence of indications of bedding in decomposed rocks which seem to be shales but may really be slates. With all deduction, however, the minimum thickness of these fossiliferous strata can hardly be less than 300 feet.

From the coast these beds extend through Crafthole to the Portwrinkle fault, up to the valley on the north side of Trewrickle. From this their northern boundary with the overlying grey slates runs eastward to Trethill House in a very irregular manner, owing to faults and folds; deflecting southward from Trethill House it assumes a more regular easterly trend till terminated by the Cawsand fault south of Antony.

Traced inland from the Tregantle Valley, the boundary between the fossiliferous beds and the grey basement slates and grits is exceedingly indefinite, and on the south of Lower Tregantle is further complicated by fault. In the mass of Dartmouth slates round Higher Tregantle synclines of Meadfoot basement beds are almost sure to occur, but the surface evidence is too meagre to attempt a separation. West of Millbrook both the fossiliferous rocks and basement beds are represented.

At Trewrickle grey-buff and whitish grits crop out. At about a quarter of a mile north-east of Trewrickle hard calcareous slates or shales with some limestone and decomposed friable residues dip south-east at about 20°. On the hill above, at a quarter of a mile east of Trewrickle, two dykes of decomposed igneous rock are visible in a quarry in greenish grits. The grits contain shaly friable fossiliferous material, and dip south at about 35°. The strike is shifted south by a north and south fault near this, and a syncline brings the grey slates from Trethill westward in the valley toward Crafthole.

On the south of Trethill House purple, yellow, and white grits, of Looe and Torquay (Lincombe and Warberry) types, with traces of crinoids, come on. Following their general strike toward Crafthole, soft arenaceous grey-green rocks with decomposed limestone and numerous distorted fossil casts are exposed in a quarry (near Liscawn Farm). The dip is south-south-east at 55°.

From here to Blarrick and Tregantle grits and arenaceous rocks of red, pinkish, buff, and whitish colours are evidenced by surface stones and in occasional exposures; friable seams and traces of fossils may occasionally be observed. The surface evidence here is so like that of Lincombe and parts of Warberry Hill, Torquay, that when this district was first explored in 1894 the rocks were taken as Staddon, an error entirely due to the acceptance of the dictum of previous observers that the Lincombe and Warberry rocks were the same series and above the Meadfoot beds. Although these rocks are described under the heading of Staddon grits in the Torquay Memoir, the probability of the inclusion of the Lincombe beds in the Meadfoot group is distinctly stated.[1]

At and near Blarrick yellow, brown, and whitish arenaceous beds and grits occur, and also yellow and red beds in which fossils resembling *Chonetes* were noticed. Brown friable fossiliferous material and purple buff and greenish broken slates, grits and shales are exposed, east of this up to, and by, the military railway from Tregantle to Scraesdon Fort where *Favosites* and *Pleurodictyum* and impressions like *Orthis* were noticed. Similar evidence is obtainable about Lower Tregantle, and at about a quarter of a mile to the east of that hamlet very fossiliferous shaly reddish rocks, recalling beds in the New Cut, Torquay, crop out. The fossils are much distorted; *Spirifer primævus* Stein. was doubtfully recognized amongst them. At about half a mile east of the church at St. John's, on the north side of the valley, there is a quarry in soft shaly beds with grits and reddish-brown decomposed fossiliferous material including crushed brachiopods, corals, and crinoids.

South of St. John's greenish and red grits and slates or shales with traces of fossils are visible between the faults, which cut them off against Dartmouth slates on the south and higher horizons in the Lower Devonian on the north.

If the southern boundary of the Dartmouth slates north of Withnoe be prolonged to the place where the fault of Inswork Brick Pits crosses, or coalesces with, the Cawsand fault, it forms the base of a scalene triangle with its longer side represented by a line drawn from the eastern side of the northernmost patch of felsite to an apex on the Cawsand fault near Millbrook Church. The area thus enclosed may be either Dartmouth slates or coloured rocks of the fossiliferous Meadfoot horizons. By the road toward Millbrook, purple, greenish, buff, and grey slates are here and there exposed, but no signs of fossils have been found in them. If Dartmouth slates, this triangular tract is enclosed by faults.

On the west of this doubtful tract yellowish-brown and grey grit-shales and slates with brown friable fossiliferous interbedded material are exposed dipping south near Millbrook and by the plantation on the map on the west side of the tributary stream which rises in the northern patch of felsite. At the road junction near Withnoe there is a small quarry in irregular grey-green slates with friable fossiliferous patches and compact brownish grit dipping south at 40°, cleavage at 60°. Further west there are signs of grit with small fossils. The extension of the basement beds through lack of exposures is very doubtful, and the relations of the Dartmouth slates may be affected by faults or plications, their boundary on either side of the Withnoe felsite being generalized and conjectural as there are no exposures or surface indications to guide one.

To the north of the fossiliferous horizons the rocks of the Meadfoot group consist of grey slates with occasional beds and seams of grit. They very rarely afford traces of fossils. The igneous rocks in them east and west of Sheviock may be intrusive diabase sills. At the Mill (Delabole Mill) east of Sheviock hard brown bands afford a pretty example of joint cleavage (Fig. 5.). Their bedding, at 30° south, traverses cleavage dipping at 65° south which is deflected in crossing them to 74° north.

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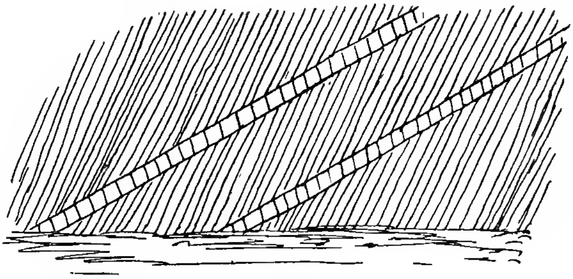
[1] "Memoir on the Geology of the Country around Torquay," p. 35.

As already stated, these beds might possibly occur at Antony and at St. John's, through the looping of the Cawsand fault. Their similarity to dark slates of the Middle or Upper Devonian in a fresh or pale weathered condition is always a source of perplexity where, as near Catchfrench, an unseen fault brings them in contact.

FIG. 5.—*Near Delabole Mill, east of Sheviock.*



The fossiliferous rocks in the Meadfoot group, as may be inferred from Mr. Collins' lists, received less attention in Sheet 348 than in the neighbourhood of Fowey and Polruan in the adjacent Map 347 on the west. The Fowey rocks present a similar development of arenaceous material to that in the fine Tregantle coast section. Probably through distortion the numerous casts and impressions of fossils have furnished a comparatively scanty fauna, though the species identified are often numerically abundant.[1]

Homalonotus, so plentiful in the Torquay promontory, is not recorded. *Phacops laciniatus* (Salter), is said to occur at St. Keyne, therefore probably in Staddon grits or Middle Devonian rocks.

Polperro is given as a doubtful locality for *Actinoceras devonicans* Whidb., this cannot be accepted without absolute proof. *Holopella* or *Loxonema* are also said to occur at Polperro; but all the fossils said to occur at Polperro, other than *Bellerophon* and fish remains, require more precise definition of locality,[2] as the rocks are Dartmouth slates. Under *Spirifer cultrijugatus,* Davidson remarks in his Monograph:[3] "This large Spirifer occurs plentifully, but in a very distorted and compressed condition, in the state of internal casts and impressions, in the Devonian grits of Looe in Cornwall." Under *Spirifer primævus* in Mr. Collins' working lists *Sp. cultrijugatus* is included as "probably erroneously identified by Rœmer."

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xi., p. 421.

[2] As, for instance, *Rhynchonella pengelliana* and *Spirifer primævus* in Mr. Collins' working list.

[3] *Pal. Soc.*, 1862, vol. xvi., p. of Monograph) 36.

The following list is compiled from Mr. Collins' Papers, Davidson's Monograph, and the other sources mentioned:—

Gasteropoda.

Pleurotomaria cancellata *Phil.* In the Looe beds according to Couch.

Lamellibranchiate.

Capulus sp. Said to occur at Millendreath.

Brachiopoda.

Atrypa aspera (*Schloth.*) ... ... Looe.

A. desquamata *Sow.* ... ... Looe.

A. reticularis (*Linne.*) ... ... Looe.

Leptœna (?) laticosta (Tropidoleptus rhenanus) *Conrad.* ... Looe.

Orthis arcuata, *Phil.* ... ... Looe.

O. hipparionyx (Orthotetes personata) (*Vanuxem.*) ... ... Looe.

Rhynchonella pengelliana *Davidson.* Flattened and distorted external impressions and internal casts in yellow sandy rock at Looe.

Spirifer barumiensis *Davidson.* ... ... Looe.

Sp. curvatus (*Schloth.*) Compressed casts, doubtfully referred to this species by Davidson, Looe.

Sp. hystericus *Schloth.* At Looe according to Holl.

Sp. lævicostus (*Valen.*) At Looe according to Etheridge.

Sp. primævus *Stein.* Looe district.

Sp. speciosus *Schloth.* East Looe according to McCoy, not corroborated by Davidson.

Spiriferina cristata (*Schloth.*) Var. octoplicata (*Sow.*) Distorted casts abundant in yellow grits at Looe according to Davidson.

Streptorhynchus gigas *McCoy.* Looe district. Quarry south of Bake. Internal casts of ventral valve according to Davidson at Looe.

Str. (?) persarmentosus *McCoy.* Common at East Looe.

Str. umbraculum (*Schloth.*) Looe district.

Corals.

Alveolites labechei *Milne Edw.* At Millendreath and Pelynt according to Peach.

Caunopora ramosa *Lonsdale.* At Looe according to Peach and Couch.

Favosites cristata *Milne Edw.* At Millendreath, Looe, and Pelynt according to Peach.

F. fibrosa *Milne Edw.* At Looe according to Couch.

Petraia celtica *McCoy.* Said to occur at East Looe.

P. trelawniensis. Species occurring at Trelawne according to Couch.

Pleurodictyum problematicum *Goldf.* Looe district, &c.

Annelida.

Nereitopsis cornubicus *Upfield Green.* Polyne Quarry.

Echinodermata.

Cyathocrinus annulatus. Trelawne, according to Couch.

C. megastylus. Whitesand Bay, according to Phillips.

C. nodosus. Chough rock near Looe, according to Peach.

Encrinites (?) glomeratus. Trelawne and Bake, according to Couch.

Chonetes is certainly present, but *Chonetes hardrensis*, said to occur in the Looe beds by Etheridge, requires confirmation, *C. plebeia*, and *C. sordida* are very much more likely to occur.

The Tregantle coast section gives a more unbroken sequence of fossiliferous beds than is elsewhere accessible in the area, and the relative positions of the fossils could be more easily ascertained, if a protracted search were undertaken with the view of ascertaining the existence and sequence of fossil zones.

Staddon Grits.

On the east side of Plymouth Sound the Staddon grits make their first appearance (in Sheet 349), at about 1,000 yards south of Mount Batten Coastguard Station, in a sharply plicated fold of hard quartzose grit in Middle Devonian (Eifelian) slates with hard brown-weathered nodules and lenticular bands and occasional seams of limestone. The junction beds, often obscured by thrusts along the inverted plications, are repeated for 300 yards. The grits then come on in force with a south-westerly strike, nearly coincident with the projection of the Staddon coast for about half a mile. The grits are reddish-grey, red, and purplish-grey, and are intercalated irregularly with grey and reddish slates, shales, and argillaceous slaty mudstone. They are excessively contorted throughout, the contortions being well shown by the thick grit beds which have been bent and crumpled without fracture. At Wyatt's Way a dark mudstone band in them contains fossils.

At Leek Bed Bay, a quarter of a mile from Staddon Point, intrusive igneous rock is visible, and near this grey rocks, which may be the upper beds of the Meadfoot group or the base of the Middle Devonian, are brought in by plication.

In a quarry above Staddon Point Fort several conglomeratic beds with argillaceous rock inclusions are intercalated in even-bedded purplish-brown micaceous grits, fine grained and occasionally flaggy. Markings resembling plants occur in them.

On the west side of the Sound the Middle and Lower Devonian junction is rendered indefinite by thrusts and plicated repetition for about 330 yards from Redding Point (about half-way between 'The Bridge' and Picklecombe Point on the map). From here, for more than a mile up to the Cawsand felsite, the low cliffs and foreshore reefs display reddish and purplish-brown and occasionally grey grits irregularly associated with argillaceous slaty and shaly materials. Although often nearly horizontal the rocks are evidently much contorted and intersected by numerous small faults and thrusts, and are penetrated by dykes of basic igneous rock in several places. Impressions resembling *Spirifer hystericus* were noticed (at Hoe Lake Point) at half a mile from Picklecombe Point.

At the base of the cliff, about 100 yards from the Cawsand felsite, an anticline of grey banded slaty rocks suggests the top of the Meadfoot group.

Traced inland through the zone of plicated junction beds the boundary of the Staddon grits is usually more or less uncertain, but is otherwise easily traced.

The argillaceous materials are sometimes interbanded with grit or arenaceous material, and where this banded association has been peroxidated, as is the case near the northern border of the mass in Pigshill Wood north of Maker Church, the deep-red and reddish-grey alternations form an easily recognizable type; but, as in the case of the red-speckled grit of Warberry Hill, these types must not be taken as indications of any particular horizons. Impressions resembling *Chonetes* were noticed in the grits near the Staddon outcrop between Maker Church and Mount Edgecumbe House.

Talus or Head masks the slope down to the shores of Millbrook Lake at Anderton, concealing the junction of the Staddon grits with the

Middle Devonian. It is probable that the grits strike across the Lake to the Southdown coast, where they are exposed in a quarry at the point, consisting of purplish, pale red, brownish, and buff grits and grit-shales, associated with slaty or shaly mudstones. Near Millbrook steamboat-pier the low shore is composed of red and lilac grits and of brown-weathered sandstones with ferruginous concentric markings. The north part of Millbrook affords no evidence south of the Inswork Pits, owing to a mask of Head.

The set of the coast at Anderton, in line with the boundary of the grits on the Southdown shore, renders a south-west fault exceedingly probable; but this is not sufficient to account for the relations of the schalsteins (Middle Devonian) on the Southdown coast to the schalsteins in Inswork Brick Pits which are evidently the same series; so that, besides the fault in the Inswork Brick Pits, bounding the schalsteins there on the south, another fault shifting their westerly continuation southward is almost necessary. On the north-west side of Penhale unctuous clay might mark the direction of such a fault, or it may form the north boundary of the Staddon grits on the south of Penhale and thence to Antony.

The evidence on the ground is altogether insufficient to show the position of the numerous faults by which this part of the district is broken up. The manner in which the Staddon grit is shown to follow the direction of the Cawsand fault appears certainly to be due to position between two faults, one of which runs from Antony, on the north side of the Church, by Wolsdon House to St. John's. From St. John's this fault may run along the grit boundary, or among the slates on the north of it (marked by the unctuous clay referred to) to Penhale, and thence across the projection of Staddon grit, or on the north of it in an easterly direction to the broad Inswork Valley, there meeting a north and south fault.

On the north of the grit boundary east of Penhale, some fossiliferous slaty mudstones in a manner recalled the fossiliferous rock at Wyatt's Way on the Staddon coast.

Between Antony and Penhale the grits and associated slaty beds, judging from surface stones and imperfect exposures, are more often grey or brown than red. This makes their separation from the higher horizons of the Meadfoot group, south and west of Antony and Scraesdon Fort, very indefinite.

The Lynher creek cuts through the Staddon grits, and by its shores and by the tributary creeks the series is very well exposed.

On the coast of Earth Hill grey Middle Devonian (Eifelian) slates with concentric ferruginous mottling are invertedly overlaid by rather even-bedded hard, greenish and whitish-grey grits and slates with films of grit, more or less rusty through ferruginous staining. The grits contain small pieces of slaty rock in places; the beds attain to 5 feet in thickness, and are in parts slaty. These rocks are repeated by constant contortion. On the south they are associated with arenaceous bands, becoming arenaceous or silty slates, the bedding being shown by the harder bands. In most cases, however, cleavage and bedding are approximately coincident.

The point between the Lynher and Sheviock Creek (Delabole Lake) is called Warren Point; the junction of the creeks is known as Wackar Lake. At Warren Point slates, with well-cleaved grit beds or argillaceous slaty mudstones, are overlain by reddish grits (probably inverted) not affected by cleavage, and to the south and west the same beds are repeated with low dips, and, as on the Picklecombe Point coast, are irregularly penetrated by dykes of peroxidated or buff-weathered igneous rock in four or five places.

At a quarter of a mile west of Warren Point, buff arenaceous rocks, with thick beds of greenish grit and hard brown grits and slates, give place to grey slates with occasional beds of grit, which may belong to the upper beds of the Meadfoot group folded up for two hundred yards. From here to the Middle Devonian outcrop, buff, reddish-grey, and brown grits, slaty, shaly, and thick-bedded, associated with slates and arenaceous beds, often rusty from ferruginous staining, are repeated by numerous contortions, sometimes accompanied by faults.

Signs of fossils were met with on the shore by Sheviock Wood at about one hundred yards from the Middle Devonian outcrop. Grits are repeated by fault or fold at about one hundred yards from the first appearance of the Middle Devonian slates, which are here partly calcareous. From this the outcrop runs westward to the Portwrinkle fault, along the slope to the south of Sconner House and Polbathick. Yellow, buff, whitish-red, and purple sandstones and grits are exposed in places by the creek (Sconner Lake) on the west of Sheviock Wood. In a quarry 590 yards north-north-east of Tredis pale buff grits, or arenaceous mudstone, and purplish slates are exposed. Pale brown grits are visible in a small quarry a short distance to the north. At about 300 yards north-west of Tredis grits, with traces of included slaty material, and sandstones partly peroxidated, were seen in a quarry.

The boundary of the Staddon group south of Tredis and Trewin House is rendered indefinite by the apparent association of grey slates with arenaceous materials, which may be due to plication of junction beds; the exposures are few and imperfect. South of Clicker Tor the Staddon grits again come on, their northern outcrop having been shifted nearly five miles to the north-west by the Portwrinkle fault.

Partly from the absence of exposures and of surface evidence in grass lands, partly from the greater prevalence of the arenaceous and argillaceous softer types, locally from marshy tracts, and very probably owing to faults of which no evidence can be obtained, their boundaries near Horningtops and Bylane End are purely conjectural, so that the suggested anticline of rocks of the Meadfoot group on the west of Bylane End is by no means certain.

A quarry about 770 yards west of Pucklepit Bridge exhibits green grits or sandstones, associated with shaly argillaceous materials and dark grits containing flat pellets of shale or mudstone. At about 300 yards west of this, in another quarry, green grits or sandstones, dipping south, rest on purple and greenish argillaceous rocks; the purple material resembles a sheared clastic rock, made up of shale fragments. To the south of these quarries a section of shaly argillaceous and arenaceous rocks is exposed in a straight bye-lane. Soft buff and brown sandstones occur at about a quarter of a mile north-west from Bylane End. Besides the above the indications of subjacent rock are confined to occasional surface stones.

About 200 yards north of Pensipple, drab-weathered sandstone, with a southerly dip, is exposed, and at a quarter of a mile east of this there is a quarry in grey and greenish rough grits or sandstones, and grey argillaceous slates or shales with arenaceous films. At Trewidland yellowish-brown sandstones and shales dip south. Buff argillaceous and arenaceous rocks are evidenced at Pensipple and near the East Looe Valley. On the opposite side of the East Looe Valley a quarry by the road shows hard, irregularly jointed, grey and dull green-grey grits, dipping south-by-east.

The irregular boundary of the Staddon grits near St. Keyne is probably due to plication, as the strike of interbedded shales and grits in the lane on the west of St. Keyne Church shows a strong southerly deflection in accordance with it.

At a quarter of a mile south of St. Keyne Church (at Ambrosehill), nearly horizontal beds of hard whitish grit, or quartzite, are associated with sandstones and argillaceous rocks in a quarry. A little south of the above, buff and drab slaty grits and argillaceous slates are shown, dipping south-south-east at a low angle.

A quarry about a quarter of a mile to the north of Bodbrane shows greenish and pale buff, rather slaty, grit or arenaceous mudstone banded in places, and with occasional slate fragments. These rocks are associated with grey argillaceous slates, and the south-by-east dip they give may be cleavage, partly coincident with bedding. A quarry in Windsor Wood, near the southern boundary of the Staddon grits, shows irregular grey slaty beds with hard grit.

In a field by the plantation (Benoak Plantation on the six-inch map) half-way between Herodsfoot Church and St. Keyne Church, in a stone heap evidently collected from the surface a mass of pale grey quartzite was found with traces of fossils amongst which a small *Tentaculites* (*grandis* ?) was discernible. This suggests the presence in the Staddon grits of beds similar to those in the same series near Moreleigh and Storridge Wood in the vicinity of the River Avon valley in Sheet 349. The Staddon grits near this are bounded on the north by pale greenish argillaceous slaty or shaly mudstone, similar to rocks at Longcombe between Paignton and Totnes in Sheet 350.

The buff and drab arenaceous association with dull greenish-weathered grit or sandstone gives place to argillaceous slates at Polvean Cross, where the southern boundary of the Staddon grits has been taken. The slates are often sufficiently tough to quarry in blocks, utilized locally for walls, &c. There appears to be some arenaceous material in them near Duloe Church, suggesting a thin outlier of Staddon grits.

On the east side of the Herodsfoot Valley, greenish-grey sandstones exhibit a south-westerly strike parallel to the boundary. The sandstones and argillaceous materials are seen to be finely laminated in places. In a quarry near the farm (Carglonnon) at half a mile south-by-east from Herodsfoot Church the laminated beds show gnarling. By following the bye-lane from this quarry for about 100 yards we encounter greenish slates, mottled purplish, interbedded in the sandstones. Purplish slates were also met with at a mile due south from Herodsfoot Post Office. These occurrences show how little value can be attached to variegation.

East of the last observation and at three-quarters of a mile due west of Polvean Cross, hard blue-grey grits and slates dip south at about 15°, with cleavage dip at 60° in the same direction. These beds are of Meadfoot type and may indicate a small infold of that series. A south-easterly fault may cross the Herodsfoot Valley at half a mile south of the village, for the boundary of the Staddon grits, from the Herodsfoot Valley westward, is anomalous.

On the west side of the valley there is a north and south silver-lead lode (or lodes) which was formerly worked at Herodsfoot Mine, about 120 yards from the alluvium of the valley and 50 yards or so north of the outcrop of the Staddon grits, and at South Herodsfoot Mine, a quarter of a mile south of Herodsfoot Mine. The tips from both these mines are dark grey slates, but the outcrop of the Staddon grits consists of buff grits, or sandstones, immediately south of the Herodsfoot Mine, and greenish and buff shaly sandstones are exposed at about 200 yards further south.

As far as the few and imperfect indications met with enable one to judge, these sandstones are either brought north of the Staddon outcrop on the east of the valley by a south-easterly fault or by a change in strike produced by flexure. A fault is the more probable supposition because the sandstones south of Herodsfoot Mine appear to strike south-west toward Pendruffle, and yet, through a fold bringing in slates with occasional beds of compact grit, the Lower Devonian boundary runs irregularly westward. If these apparently underlying slates are a lower horizon in the Staddon grits, or the upper part of the Meadfoot beds, their position must be due to a thrust fault of considerable magnitude, and the sandstones outcropping on the west side of the valley must be much lower than those outcropping on the east side, otherwise the slates with occasional grit beds are a local repetition of Lower and Middle Devonian junction beds, in which case the shaft of the South Herodsfoot Mine would be sunk in Staddon grits and the Herodsfoot Mine shaft ought to reach that division at no great depth from the surface. The importance of ascertaining the structure here cannot be overrated, for the north-westerly deflection of the Staddon grits toward Bodmin takes place at about a mile and a quarter west of the border of the map, in Sheet 347, where they are shifted northward by fault.

The distribution of the lead lodes shows an avoidance of divisions of an arenaceous character; they are found in the Upper Devonian and Middle Devonian slates and in the most argillaceous portions of the Meadfoot group, so that their occurrence at the outcrop of the Staddon grits in Herodsfoot Mine and apparently in that series in South Herodsfoot Mine is suggestive of thrust faults on rather a large scale, or of thrusts co-operating with ordinary faults sufficient to bring slaty rocks into positions in which we should ordinarily expect to find more or less arenaceous rocks in depth.

The "slidy ground" encountered in the mining operations, and described as "having an imperfect laminated structure," may be evidence of these disturbances. Mr. Collins[1] quotes the following description of it: "The whole strata seem to be broken up by a succession of disturbances of a nature between cross courses and slides. . . . This broken ground generally extends for a considerable width, shattering and, indeed, obliterating the lodes. . . . Its width in Herodsfoot is about 60 fathoms at surface, and 30 fathoms at a depth of 150 fathoms (the course is nearly E. to W.) . . . the broken ground has been passed through, and what is to all intents and purposes a new mine has been opened out south."

[1] J. H. Collins. *Trans. Roy. Geol. Soc. Corn.*, vol. xii., pp. 695-697.

Within half a mile of Herodsfoot Church on the north-east a few grit fragments have been noticed amongst the slate surface stones; if not brought with manure they may indicate a small anticlinal appearance of the Staddon grits, but the evidence is obviously untrustworthy.

Between Trevelmond and Bosent the rocks seem to have a slightly arenaceous or silty character; pale buff slates and mudstones are exposed. This type is also present north-north-east of Bosent. It suggests anticlines of Lower Devonian, but, as this cannot be proved, it is safer to regard the occurrences as denoting a slight variation in the Eifelian (or Middle Devonian) slates.

Igneous Rocks in the Lower Devonian.

With the exception of the porphyritic felsites of Cawsand and Withnoe the igneous rocks in the Lower Devonian area in Sheet 348 are confined to small patches, mostly intrusive pipes, dykes, or sills, and too small to be indicated by colour on the map; these can in no case be traced with certainty for any considerable distance even where their association and appearance in spite of decomposition render it probable that they may be contemporaneous. The following occurrences of igneous rocks have been noted in the coast section proceeding westward:—

In Staddon grits—on the eastern margin of the map, in Leek Bed Bay, nearly 400 yards north of Staddon Point, intrusive igneous rock, strata much disturbed at contact.

Mount Edgcumbe coast near Picklecombe Fort, in Staddon grits and shales much faulted and contorted—traces of intrusive igneous rock much decomposed. At a quarter of a mile from Picklecombe Point proceeding towards Cawsand—a dyke and rock resembling a volcanic breccia or agglomerate. At 120 yards further—several dykes in the low cliff. Between 80 and 170 yards further on, dykes of peroxidated igneous rock, which appears to have been porphyritic diabase, are observable. Between this and the Cawsand felsite two more dykes of igneous rock are visible in the Staddon grits.

The Meadfoot beds are cut out by fault at the termination of the felsite in the Cawsand Valley. Proceeding thence round Rame Head, the following occurrence of igneous rocks, in some cases doubtful, were noticed in the Dartmouth slates:—

A little sheared diabase about a quarter of a mile north of Penlee Point, perhaps an east and west sill.

North of Rame Head, at about 160 yards from Queener Point, two to three feet of sheared diabase, and at 60 yards from the point two feet of decomposed igneous rock. Above Queener Point a trace of diabase in the crags. In the cliffs under the Coastguard Station, at about 400 yards north of it, dark green igneous rock, seemingly intrusive, is visible; quartz-albite veins occur in the slates to the south. There may be a trace of igneous rock at a fault under Wiggle Cliff, about 800 yards further north. At 1¼ miles from the Coastguard Station, a small patch of diabase is visible under Trewinnow Cliff. A trace of green sheared igneous rock is present in the coast road on the west side of the Freathy Valley. Porphyritic diabase, possibly at a synclinal axis, is visible in the cliff 100 yards beyond Sharrow Point, and a sheared igneous rock, probably in the upper part of the Dartmouth slates, is visible at about 250 yards further on.

There appears to be a decomposed volcanic rock in beds of the Meadfoot group near Freathy on the east. A pale weathered diabase and a rock resembling a fine tuff occur in dark slates probably in the lower part of this group on the south side of the valley, half-way between Millbrook and Withnoe. With the exception of the two felsite patches near Withnoe, and a sign of igneous rock much decomposed near the outcrop of the Staddon grits south-west of Mount Edgcumbe House, igneous rocks have not been recognised in the Lower Devonian area inland, east of Freathy. Rocks of the Meadfoot group occupy the coast of Tregantle; the signs of igneous material in them are too decomposed for determination. Small patches of sheared igneous rock occur at the fault at the head of the little valley south of the church at St. John's, and at half a mile west of St. John's. A larger mass is exposed in Ladywell Quarry near Sheviock, and bands or sills are visible further east, on the north shore of the estuary, in grey slates, probably in the upper part of the Meadfoot group; another mass occurs in the same or similar rocks in a valley three-eighths of a mile south-west of Antony. There is a small patch of igneous rock in Antony churchyard, but whether it occurs in Lower Devonian or Eifelian slates is doubtful. Another mass of basic igneous rock, probably a sill, occurs in the grey slates north of Tredrossel, west of Sheviock. Dykes of igneous rock were seen in a quarry about 600 yards north-west of Crafthole. There are signs of intrusive dykes in the Staddon grits at the bend in the Lynher estuary south of Earth Hill.

To return to the coast, proceeding westward—

At a mile and a half from Sharrow Point igneous rock occurs at a fault taken as junction between Meadfoot group and Dartmouth slates. At 700 yards from this, near Hilstor rock, an igneous mass at the base of the cliff terminates irregularly upward, cutting off the cleavage planes of slates with harder siliceous interlamination; whether the irregular junction is due to intrusion or plication is not certain. There is a trace of igneous rock on Finnygook Beach, east of Portwrinkle.

At The Long Stone, west of Portwrinkle, two masses of diabase form the horns of the promontory, on the east side of which igneous rock (a sill or contemporaneous band), touches the cliff in two places, and appears to run along the foreshore toward the point.

The rocks of The Long Stone were described by Worth,[1] who quotes Prof. Bonney's remarks on specimens submitted to him. One of these appears to have been "a compact basic lava," the other "a holocrystalline rather felspathic dolerite with ophitic structure."

From here to Seaton Beach no certain traces of igneous rocks were observed in the Dartmouth slates. There is a patch of rock, seemingly tuff, in an inverted syncline near the limekiln at Seaton Beach. In the Dartmouth slates which form the cliffs for more than a mile and a half west from Seaton Beach, small patches of diabase are observable in seven places, at about a quarter of a mile, a half mile, three-quarters of a mile, and a little over a mile from Seaton Beach. The mass nearest to Seaton Beach appears to have its upward extension in the cliff cut off by an overthrust. Diabase occurs in the dark slates with fish remains, at about 600 yards from Millendreath Beach, and in the fossiliferous beds about 180 yards from the Beach.

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xi., p. 50.

Between Millendreath and East Looe bands of decomposed rock, apparently volcanic, are encountered in, or above the cliffs here and there, and in one place the igneous rock may be intrusive.

Between Looe and Portnadler Bay two small patches (one of porphyritic diabase) are visible on the shore, and a decomposed patch above, in the vicinity of the stream valley. Between this and the Portnadler fault, decomposed igneous rock occurs in two places. On Looe Island there are four small patches of hard diabase in the Dartmouth slates.

Igneous rock is noticeable by the road from Talland Bay to the church, and the same band displaced by fault, or other bands, are exposed in the low cliff or beach reefs of the inner shores of the Bay. A trace of igneous rock was also noticed at about half a mile east of Polperro Harbour.

The shores of the East and West Looe creeks afford many examples of igneous rocks in the rocks of the Meadfoot group; these are more frequent in the grey slates with calcareous bands than in the grit developments. These rocks occur pretty much in the same way as they do in the Torcross and Ringmore types in the Kingsbridge and Salcombe area. Besides patches of diabase, there are bands of contemporaneous volcanic rock which can never be, collectively or individually, traced on their strike for any distance, as a rule not beyond their actual exposure. The thin sheets or seams of tuff or lava have been sheared out along thrusts and contortions, and so displaced that continuity can scarcely be expected. To particularise every instance where igneous rocks have been observed, as in the coast section, is unnecessary, as they are in so many cases through decomposition rendered petrologically valueless.

West Looe River, a mile and a half up stream from its confluence with East Looe River, igneous rocks in nine places on left, and in three places on right, bank. In a mile above this igneous rocks were noticed in five places on the west bank, one band being traceable for about a quarter of a mile in a south-westerly direction. On the opposite slope in two places (south of Polpever, and south of Hillhead). Above this, opposite St. Ann's Well (St. Nun's on 6-inch map), sheared diabase is visible in two places. In the grey slates (upper part of Meadfoot group) and Staddon grits from this northward no igneous rocks were noticed. There is a tuff (apparently) in the slates just near Looe Station, and further north, west of St. Martin, near the fish pond. At half a mile further north, igneous rock is seen in a quarry of slate with limestone; this rock, crossing the East Looe in a south-westerly direction, is seen in a quarry on the west bank, and it may be continuous to the north-east, with an igneous rock exposed south of Morval Farm. At the lodge of Trenant Park, near this on the south, a little sheared diabase was seen with calcareous beds. Sheared diabase occurs in Westnarth Wood, opposite Plashford, and in the slates and calcareous beds near Plashford on the north and east.

There are traces of sheared igneous rock near Wringworthy, east of Plashford, by the high road to Bin Down, at a mile from St. Martins, and near Shorta Cross; and in the Dartmouth slates on the east of the Seaton Valley, between Bake Wood and Bonialva, east of Deviock, and near Narkurs, which may be contemporaneous bands.

As the igneous rocks in the above notes are for the most part too thin and insignificant to be shown on the one-inch scale without gross and unwarrantable exaggeration, their occurrence has been mentioned in more detail than their importance might seem to justify. An interesting intrusive

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. xi., p. 50.

igneous rock is quarried for road metal on Bin Down. Dr. Teall described it in 1901—slides 3254, 3255—as "grey or bluish-grey highly quartzose rocks traversed by veins of quartz and pyrite. Under the microscope, they are seen to be highly silicified vesicular igneous rocks. Quartz has been deposited not only in the veins, but also in the vesicles. The greater part of the rock is composed of quartz, but a certain amount of altered igneous material occurs as a matrix between the amygdaloids. This consists of a few rare phenocrysts of felspar in a groundmass of felspar microlites and ill-defined interstitial matter. The nature of the original rock cannot be determined with certainty from these specimens. It appears to have been either an andesite or trachyte—most probably the latter." At first sight this rock might be mistaken for a pebbly grit. Its westerly prolongation is based on occasional surface stones, and is therefore very doubtful.

The following note is by Dr. Flett: Excepting the above, of the igneous rocks mentioned in this chapter only two are represented by slides in the Survey collection (4335, Trewinnow, and 4336, Looe Island). They are both much sheared and badly decomposed basic rocks, full of chlorite and pyrites, but still containing a little fresh felspar, undecomposed pale brown augite, and, in the Looe Island rock, a little dark brown primary hornblende. Remains of ophitic structure are visible in both, a fact which makes it probable that they are intrusive.

CHAPTER III.

MIDDLE DEVONIAN.

The Middle Devonian rocks on entering Cornwall are largely cut out by faults, especially in the vicinity of Millbrook. Moreover, the abrupt termination of the limestone near Cremyll deprives us of the only definite lithological boundary between Upper and Middle Devonian slates in an area where the outcrops are shifted by great faults and the rocks are repeated by innumerable folds. This involves some reiteration of descriptions in this and the succeeding chapter.

The Cawsand and Portwrinkle faults divide the recognisable Middle Devonian rocks into three districts:—1. The Plymouth district—from the Cawsand fault at Antony eastward. 2. The St. Germans district—between the Cawsand and Portwrinkle faults. 3. The Liskeard district. In the St. Germans district the mass of schalstein has been taken provisionally as the north border of the Middle Devonian, but the dark slates north of the Polbathick Valley present no specially distinctive characters and have yielded no fossils by which their age could be determined. In the Liskeard district dark slates north of Dobwalls, which might belong to the Upper Devonian, are included in the Middle, and it is most uncertain as to whether the rocks between Merrymeet and Quethiock may not partly belong to the Middle Devonian. This uncertainty is due to dark slates taking the place of the limestone, being only distinguishable from dark slates locally representing the lower beds of the Upper Devonian by fossil evidence. The presence of variegated slates in the Middle Devonian south of Barn Pool on the Mount Edgcumbe coast, near Impacombe, and probably also east of Mutton Cove, does not tend to lessen this uncertainty.

That the Plymouth limestone is in part at least equivalent to the upper parts of the limestone masses of the Torquay area is evident from the brachiopods contained in it, which are with very few exceptions common at Lummaton and Wolborough. Moreover, according to Davidson, *Rhynchonella cuboides* (Sow.), is common in it. Its base, however, is by no means clearly defined owing to vulcanicity.

Plymouth District.

The limestone forms a plateau, as pointed out by Worth,[1] of much lower elevation than the slate hills, "averaging about a hundred feet." "It varies much in colour, structure, and dip. Its most constant features are its crystalline character, and the regularity of its divisional planes." "Bedding is frequently indistinct, and in some central parts of the mass apparently non-existent. It abounds in fossils—chiefly coralline in its more massive portions; whilst some of the exterior beds have yielded large quantities of bivalves and univalves; and others, with the adjoining slates, are remarkably fruitful in crinoidal remains. In texture it is generally highly crystalline, and in colour very various, ranging from black through red, yellow, brown, dove and gray to white." "At Cattedown [Catdown on the present map] there is a shallow synclinal and some undulation, but the prevailing dip is toward the south."

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[1] R. N. Worth, 'The Geology of Plymouth.' *Journ. Plymouth Instit.*, 1875.

Worth also notes the dolomitic character of parts of the Plymouth limestone and the occurrence of "sandy as well as slaty limestone. Treating a reddish-coloured arenaceous limestone from the Hoe with dilute hydrochloric acid," he "found that 25 per cent. of its bulk consisted of a bright-red siliceous sand, exceedingly fine. The stone was of the kind known to the quarrymen as 'hard head,' which occurs more or less intermixed with the limestone proper throughout its range." In another place he draws attention to material from the New Red filling joints in the limestone. Good examples of red sandstone filling joint cracks and fissures are to be seen in the shore reefs of the Barn Pool limestone near Cremyll.

Worth[1] gives the following list of corals from the Plymouth limestone, with localities:—

Amorphozoa.

Stromatopora concentrica	Cattedown.
Str. placenta	Cattedown.
Str. polymorpha	St. George's Hall Millbay, Teat's Hill.
Str. ramosa	Cattedown.

Cœlenterata.

Acervularia goldfussi	Cattedown.
A. intercellosa	Cattedown.
A. pentagona	Cattedown.
Alveolites vermicularis	Mount Wise, Devil's Point, Millbay, St. George's Hall, Cattedown.
Amplexus tortuosus	Mount Wise (?)
Cyathophyllum helianthoides	Mount Wise, Devil's Point.
Cystiphyllum damnoniense[1]	Mount Wise, Cattedown.
Cystiphyllum vesiculosum	Mount Wise, Cattedown.
Favosites goldfussi	Devil's Point.
F. cervicornis	Cattedown.
F. fibrosa	Cattedown.
Heliolites porosa	Cattedown.
Pleurodictyum problematicum	Cattedown.
Petraia celtica	Cattedown, Mount Batten.
Smithia hennahii	Cattedown.

Scyphia turbinata and Spongophyllum sedgwickii are given without localities.

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[1] 'The Palæontology of Plymouth.' *Journ. Plymouth Instit.*, 1878.

[2] *Cystiphyllum damnoniense* Lonsd. is the original name afterwards changed to *Cyathophyllum damnoniense.*

Davidson says[1]: "Several localities in the neighbourhood of Plymouth have afforded Brachiopoda, but Mount Wise appears to be one of the more important spots. I am informed by Mr. Champernowne that shales with bands of nodular limestone with *Orthis arcuata* and *Atrypa reticularis*, resting conformably on the Upper and Dolomitic beds of Limestone, occur at Mutton Cove, near Mount Wise. A little way down in the limestone is a group of Brachiopods agreeing closely with that of Lummaton, Woolborough and the Upper Dartington beds, of a very limited thickness, among which *Rhynchonella triloba*, *Rh. cuboides* and *Merista plebeia* are conspicuous."

A tabular scheme of Champernowne's for a correlation of the limestones is given by Davidson, in which the shales, &c., with *Orthis arcuata* are correlated with the Hopes Nose beds. The locality mentioned as "Mutton Cove" is at the entrance to Coles' timber-yard, and will be referred to later on.

The locality "Dock Yard" in Davidson's descriptions is synonymous with Devonport, which was so-called until 1884.[2] St. George's Hall and Stonehouse are synonymous. As regards trilobites, Worth mentions the occurrence of fragments at Mount Wise and among rubbish from the site of the Plymouth Guildhall.

He gives one cephalopod, *Orthoceras cinctum*, or *undulatum* (?), from Mount Wise and St. George's Hall. Worth's list of gasteropods includes:—

Acroculia vetusta (?) ...	... Mount Wise.
Euomphalus radiatus ...	... St. George's Hall.
Macrocheilus imbricatus	... St. George's Hall.
Murchisonia spinosa ...	... St. George's Hall.
Turbo cirriformis ...	... Stonehouse according to Whidborne.
Bellerophon striatus ...	... Mount Wise.

Loxonema (*Holopella*) *hennahiana*, *L. præterita* and *Macrocheilus harpula* are given without localities. In this and other cases where Plymouth is given as the locality without nearer specification the species have no absolute stratigraphical value and may have been obtained from localities in the adjacent map. Cattedown is partly in Sheet 348 partly in Sheet 349.

Worth gives only three lamellibranchs: *Conocardium aliforme* (?) from Mount Wise, *Pterinea texturata* from Millbay, and *Corbula hennahii*—locality not specified.

The following list of the brachiopods is from Davidson's Monograph and Supplement, with localities supplemented by Worth, &c.:—

Terebratula sacculus (*Martin*), var. hastata *Sow.*, at Mount Wise according to Worth.

Terebratula juvenis (*Sow.*), Mount Wise according to Worth.

Stringocephalus burtini *Defr.*, Mount Wise and St. George's Hall (Worth).

Merista plebeia (*Sow.*), Mutton Cove (Worth), Mount Wise, Stonehouse.

Retzia longirostris *Kayser* (not R. ferita *von Buch.*), Dock Yard.

Spirifer nudus (*Sow.*), Dock Yard.

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[1] *Pal. Soc.*, vol. xvii., p. 124.

[2] *Ibid*, vol xxxvi., p. 30.

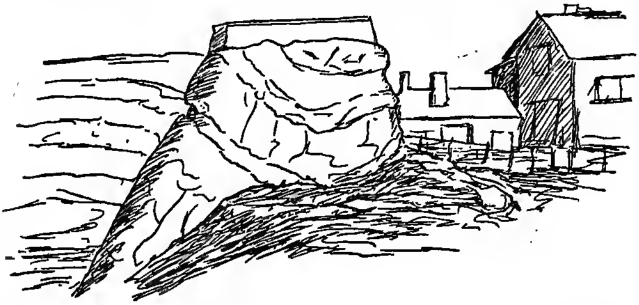
Cyrtina heteroclyta (*Defr.*), Mount Wise (Worth).
Atrypa reticularis (*Linn.*), Mutton Cove, Mount Wise, Millbay (Worth).
A. aspera (*Schloth.*), Dock Yard (Worth).
A. desquamata (*Sow.*), Mount Wise (Worth).
Rhynchonella triloba (*Sow.*), Mutton Cove (Worth).
Rh. pugnus var. anisodonta (*Phil.*), Mount Wise.
Rh. cuboides (*Sow.*), Mutton Cove, Mount Wise, St. George's Hall (Worth).
Rhynchonella primipilaris (*Von Buch.*), Dock Yard, Mount Wise (Worth).
Rh. implexa (*Sow.*), Dock Yard, Mount Wise.
Rh. (Camarophoria) protracta (*Sow.*), north side of Stonehouse limestone hill (Davidson), St. George's Hall (Worth).
Pentamerus brevirostris (*Phil.*), St. George's Hall (Worth).
Strophomena rhomboidalis (*Wilck.*), var. analog a (*Phil.*), east of Mutton Cove (Ussher).
Orthis striatula (*Schloth.*), St. George's Hall (Worth).
O. arcuata *Phil.*, east of Mutton Cove (Ussher).

Without nearer specification than Plymouth the following are given:—*Rhynchonella crenulata*, the original example, *Rhynchonella acuminata* (omitted by Worth), *Leptæna* (*Strophomena*) *interstrialis*, *Productus subaculeatus* (*P. fragraria* Sow.), *Productella fragrina* (Whidb.). Worth also gives *Rhynchonella reniformis* and *Streptorhynchus crenistria* without localities. All the above brachiopods occur in the Lummaton or Wolborough fauna, except *Orthis arcuata* and *Streptorhynchus crenistria.*

On the north of the limestone from Mutton Cove to Stonehouse Bridge a belt of volcanic rock is indicated on the map. It is merely a zone within which volcanic rocks are known to occur in the slates. The tower in front of the Devonport Guildhall stands on a rock composed of red and greenish slates, apparently faulted against grey brown-weathered slates overlain on the south by grey brown-weathered igneous rock.

In drainage operations at Raglan Barracks, in May, 1898, in the main drain crossing the high road at about 60 yards from the garrison chapel, slates were exposed on either side of the road; but, in the continuation of the drain by the women's hospital, green-grey buff-weathered igneous rock with small calc-filled vesicles was disclosed; it continues eastward on the summit near the high road. On the opposite side of the road the limestone forms a cliff which can be followed round to the large quarries on the west of Stonehouse Pool. The synclinal structure of the limestone is very distinctly shown at the end of the cliff nearest to Stonehouse Bridge (see Fig. 6). A path about 180 yards to the west, called the New Cut, follows a trench cut through the limestone to the large quarries. Here, also, the synclinal structure is unmistakably shown. At its northern edge the limestone is more or less slaty and broken, but at 20 or 30 yards to the south the rock presents a massive bedded aspect with cleavage tendency. It is a pale grey coral mass with large stromatoporoids amongst a matted mesh of finer coralline materials, showing more or less distinct even bedding in places. Amongst the corals *Cyathophyllum cæspitosum*, *Favosites cervicornis* and large zaphrentids are noticeable. The axis of the syncline is shown in a saucer-shaped mass on top about 18 yards in length. To the south of this, near where the path enters the upper part of the quarry face, red and buff limestone occurs irregularly in the grey, without regard to bedding. As the quarry is followed southward the bedding is either more or less horizontal, or along the strike of a westerly dip for about 50 yards or so up to a fissure; beyond this a more or less pronounced southerly cleavage dip of about 55° gives the rock a shattered appearance indicating changes in dip. (See Fig. 7.)

FIG. 6.—*Near Stonehouse Bridge. Termination of the Limestone.*



At the southern end of the quarry, at the entrance of Coles' timber-yard, the limestone dips south at from 40° to 45° under yellow-weathered greenish schalstein tuffs; these are about 20 feet in thickness, and with a dip of 45° pass under irregular shaly limestone resembling the Hope's Nose limestone and full of fossils, brachiopods, bryozoa, crinoids, &c. These beds are a mixture of shale with lenticular limestone and occasional thin-bedded limestones; they may be about 40 feet thick and are succeeded by dark grey shales or slates.

Near an inn south of the above there is a sign of outcropping igneous rock and of red and grey broken shaly limestone, but no means of tracing either. On rounding the promontory we meet with grey slates, with lenticles and bands of limestone in places, at the Victoria Cottages. Immediately west of this the bathing-place has recently been made to which access is obtained by steps in two places from the road above. On descending the first steps we encounter the irregular shaly limestones of the Hope's Nose type, associated with slate, and dipping south to south-east at 45°. There may be 30 to 40 feet of these calcareous beds in which *Strophomena rhomboidalis* was found. A bed of tuff or schalstein about five feet thick is then encountered dipping at 45° in the same southerly direction, and intersected by a thrust which does not seem to displace the rocks much. Near this the grey slates with nodular limestone are intersected by two small thrusts, and seem to pass, through buff and grey tints for five feet, into variegated yellow, green, and purple-red slates, containing irregular nodular limestone for five feet, then for fifteen or twenty feet without calcareous materials.

These variegated slates resemble Upper Devonian rocks near the limestone border in Saltram Park[1] and bordering the Ilsham[2] limestone; they exhibit a cleavage dip of about 60° to south or south-east, and rest on an irregular surface of more or less massive red and grey limestone, which seems to be in part dolomitic. The junction plane dips south or south-east at about 30°. The distribution of the variegation is irrespective of cleavage and affords no indication of bedding which seems to cross the cleavage in thin yellowish coloured seams. From here to Mutton Cove nothing but the massive limestone was visible.

The conclusion one would naturally come to is to regard the variegated slates as directly above the massive limestone as at Ilsham, and cut off on the east by a thrust fault bringing on volcanic rock in Eifelian slates and limestones, but I cannot prove that the thrusts have more than a small and immediately local effect. It is, however, possible that an indication of thrust with a southerly dip of 40° (on the east of, and near, the volcanic band) may bound the shaly fossiliferous limestones on the north, all along their line. Otherwise the variegated slates of this section would occur between the massive and the shaly limestones.

All the apparently obvious evidence goes to favour Champernowne's opinion that these shaly beds with *Orthis arcuata* are above the massive limestones. On the other hand, the irregular resistance to compression which the solid reef limestone, occurring amongst much less coherent materials, could not fail to produce must necessarily have occasioned fractures and displacements tending completely to obscure the true succession; this, I think, can be proved by the structure of the limestone on the eastern margin of the map, taking in Catdown which is within the border of the adjacent map (Sheet 349).

The projection at the mouth of Sutton Pool terminating at the east pier forms a ridge of pale grey coralline limestone dipping south at 75°. Following this ridge for 80 yards eastward we come to a large quarry, which affords sections of the strata from the crest of the ridge to the margin of Sutton Harbour.

The west side shows more or less massive grey limestone with calc-spar veins overlying, with a southerly dip of 75°, irregular shaly and more or less nodular coralline limestone associated with dark shale. The nodular character and irregular association with shale in the thin limestones is due to segregation round corals of various sizes, individual or matted; in the latter case giving rise to more continuous beds. A large *Cyathophyllum* (? *C. damnoniense* Lonsd.) was noticed. On the opposite, or east, side of the quarry the section is about 20 yards longer, and an irregular contortion is noticeable in the massive beds, near the surface, at their junction with the shaly beds. In the latter a large compound coral resembling *Smithia hennahi* (Lonsd.) was noticed in lenticular limestone imbedded in dark shale partings; further on, through abundance of *Stromatopora*, the limestone has a pale grey tint and is more continuous; it would, in fact, if horizontal, have presented a massive appearance.

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[1] In Sheet 349, east of Plymouth.

[2] In Sheet 350, in the Torquay promontory.

These thin limestones resemble the basement limestones of Tuckenhay Creek and elsewhere, as well as those of Hope's Nose. I think they belong to the lower part of the Limestone Series. The associated shales appear to be indurated in one place where yellow friable bands occur which might possibly be of volcanic origin.

The relations of the limestone to the slates on the north are not visible. At about 80 yards north of the boundary variegated slates are exposed, and the same series extends northward to Friary Station. On retracing our steps to the ridge and following the coast southward we find that the high southerly dip of the massive grey limestones gives place to a series of undulations in the bight immediately south of the promontory ridge (named Teat's Hill) which are tantamount to a low southerly dip, maintained for about 200 yards, when the limestone becomes slaty, the cleavage dipping south at 45°, and bedding in the same direction at about 20°. This dip gradually gives place to horizontal bedding in Deadman's Quarry, where the massive beds exhibit a gentle syncline rising to the south. Toward the south end of the promontory the dip is to the south, probably at about 30° or 40°. (See Fig. 8.)

On crossing the Catwater to Turnchapel we encounter the most southerly parts of the reef, which consist at Mount Batten of bedded grey coralline limestones dipping south at angles of 60° to 80° or vertical, bounded by volcanic tuffs, under or over them (through dovetailing).

Most part of Drake's Island consists of these volcanic rocks, Their junction with the limestone is repeated by plication at the north end of Drake's Island, and on the south of Mount Batten Coastguard station.

With the volcanic rocks slates are associated, and slates with limestones and occasional volcanic rocks continue the section south of Mount Batten to Dunstone Point (in Sheet 349), which consists of irregular slaty limestone beds, probably represented by limestones shown on the map in Mount Edgcumbe Park (south of Barn Pool). At Cremyll pale grey limestones seem to dip east, off igneous rock (probably an intrusive boss). The Cremyll limestone is separated by flat ground, affording no evidence of the nature of the subjacent rock, into two patches, which may or may not be connected. The easternmost patch which may be called the Barn Pool limestone is well shown in beach reefs of pale grey and reddish compact and coralline limestone with *Stromatopora* and *Stromatactis*, recalling the Petitor limestones and identical in character with limestones in Devil's Point, Stonehouse Hill, and the Hoe.

Messrs. Hill and Co. encountered igneous rock in blasting operations to deepen the channel between Devil's Point and Barn Pool, but the Barn Pool limestones do not appear to be in contact with igneous rock. On the contrary, on proceeding southward we encounter purple and green slates, apparently in grey slates with hard limestone nodules, or nodular lenticles, and these give place to slates with pale patches or lenticles of limestone in aspect like a coarse breccia, and strongly suggestive of the replacement of limestone by slate. Further on igneous rock, apparently contemporaneous, seems to overlie these beds, and passing under grey slates on the south may be cut off by an east and west fault at 40 or 50 yards from a mass of calcareous rocks consisting of slates with lenticles of limestone and interlaminated shale and limestone. Further on more volcanic rock is met with, then slates with brown bands, and occasionally bands and lenticles of limestone, making confused, contorted, and partly faulted junctions with the Lower Devonian near Redding Point.

The Impacombe coast, from the igneous mass near Cremyll, consists chiefly of grey slates or slaty shales with nodules, lenticles, and impersistent beds of limestone in places, often decomposed. Thin volcanic bands are locally visible. About 20 feet of bluish bedded limestone comes on at 300 yards beyond Impacombe; following this band east from the coast we come to a quarry on the summit where the limestone may be 30 or 40 feet thick. It is rather difficult to account for this mass, which does not resemble the Cremyll limestones, unless we ascribe its apparently sudden development to a fault cutting off its further extension. Immediately south of this limestone development on the coast we encounter red and green slates, giving place southward to red and grey partly calcareous slates with friable residues; there is rock here, possibly volcanic, and a fault bringing on grey slates of the Berry Park type with fossiliferous lenticles. Further on the bedding is well indicated by buff and yellow-weathered shales, with a local tendency to slaty cleavage where undulating. These beds may have been a partly calcareous interlaminated group.

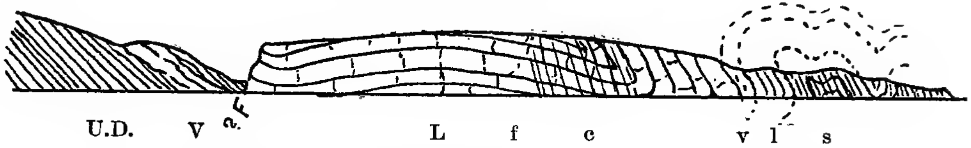
At Lower Anderton a decomposed yellow-brown mass of volcanic rock in them is cut off by fault, and further west their junction with the Lower Devonian is obscured by Head.

The relations of the limestones to the slates on the north are not shown either at Mount Wise or Catdown.

In parts of its course the north boundary of the Mount Wise limestone is marked by a nearly vertical cliff. It is difficult to explain this abrupt termination otherwise than to regard it as more or less coincident with the natural margin of the reef, a surmise which renders a strike fault with a downthrow to the north very probable. In the accompanying diagrammatic section, Fig. 7, taken along the face of the large quarry and through Coles' timber-yard, a sharp syncline is shown at *c* where the limestone is shattered and roughly cleaved. A fissure was noticed at *f*. Through this inversion the tuffs (*v*), shaly limestone (*l*), and slate (*s*) are brought up and repeated by folds on the south.

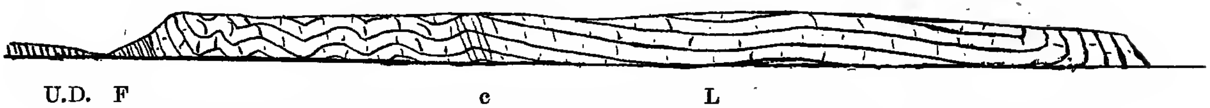
The highly inclined limestone beds on the north margin of the Catdown mass appear to be in their true position, below the massive limestones on the south. The latter are kept at the surface by a series of small curves giving place (at a point where the rock exhibits a tendency to cleavage (*c*)) to gentle

FIG. 7.—*Structure of the Limestone of Mount Wise.*



U.D. Upper Devonian, variegated slates, with V. volcanic rock. ? F. Probable fault.
L. Middle Devonian limestone, cleaved at c. f. Fissure in limestone.
v. Tuff. l. Shaly limestone. s. slates.

FIG. 8.—*Structure of the Limestone of Catdown.*



U.D. Upper Devonian, variegated slates. F. Fault, position uncertain. L. Middle Devonian, limestone, with tendency to cleavage at c.

undulations, as shown in the diagram, Fig. 8. The sharp syncline and high dip shown near the southern end of the diagram is purely conjectural. There is, however, positive evidence of the termination of the limestone in sharp plications on the Mount Batten shore, where the lower part of the reef rests on, or dovetails into, volcanic rocks and slates and limestones, these materials having partly replaced the lower beds of the reef.

It will be seen that in both the Mount Wise and Catdown sections the central part of the reef proved sufficiently rigid to retain approximately its original horizontal bedding or lines of growth, whilst the extremities were sharply folded and dislocated.

The northern boundary of the Stonehouse limestone is not exposed. Slates were seen in drains and foundations at about 170 yards west, and a quarter of a mile east, of the Octagon.

On the west side of Martin Street, at about 100 yards from the Octagon, a sinking was made through eight feet of alluvial deposits, in red slates penetrated to a depth of 20 feet.

On the opposite side of the street, at about 30 yards south-east from the above, a boring was put down in 1896 at Mr. J. Godfrey's Octagon Brewery by Messrs. Isler and Co. to a depth of 469 feet 7 inches.

The general downward succession is as follows:—

	Ft.	in.
Slate	16	0
Limestone, red, blue, and grey	142	0
Red marl	25	0
Grey and red limestone	286	7

The red marl which seems to divide the limestone into two groups suggests red slates or volcanic rocks.

Although an abundant supply of water was obtained it proved to be salt, and could only be used for cooling purposes, being unfit for brewing.

Between Martin Street and Millbay Station a boring was made for the Victoria Spa in Bath Street. Worth[1] gives the details as follows:—

	Feet.
Earthy clay slate	20
Limestone	150
Blue slate	20
Red sandstone	3
Limestone	50
Sandstone	4
Red and blue slate	30
Dunstone	8
Earthy clay slate	20
Red sandstone...	12

"The slate appeared to come in in wedges. Allowing for dip, the actual thickness of the beds traversed would certainly not exceed two-thirds of these amounts."

East of Millbay Station, in Athenæum Street, greenish slates, under made-soil with human bones three to eight feet deep, were exposed in drainage operations for 70 yards south from Millbay Road; then friable dolomitic limestone, red limestone, and slate for about 30 yards; then greenish slates for about 20 yards; beyond this, limestone, which is probably faulted. In foundations for the continuation of the Crescent to Athenæum Street dolomitic limestones appeared to be faulted against dark blue-grey limestone associated with shale and shaly limestone.

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[1] *Trans. Plymouth Instit.*, vol v., p. 459.

From Athenæum Street the limestone boundary runs to the south side of Princes Square, limestone partly shaly having been proved in Windsor Lane leading to the Hoe, and further east in Zion Street, where it is dolomitic. At the end of Zion Street, between Princess Place and Notte Street, 25 feet of slate was exposed in a drainage shaft. From Zion Street the limestone boundary runs to the Barbican, and on the other side of the entrance to Sutton Pool is continued eastward by the shaly coralline limestone already mentioned.

The engineer to the Plymouth Sewage Works, Mr. Victor Prigg, kindly conducted me through the main tunnels under Bedford Street and George Street from the foot of the shaft at the junction of these streets in front of the Prudential Buildings. The shaft is in dark slates traversed by hard pale grey irregularly jointed igneous rock with small calc-filled vesicles, similar to the rock in the Raglan Barracks drain. The bottom of the shaft is in slate. The igneous rock comes on at the entrance to the George Street tunnel and continues for 29 feet, giving place to dark grey slates which extend for 39 feet. Limestone is then encountered for 242 feet. The rock varies in character; it is for the most part a hard irregular dark grey limestone with water-worn cavities and fissures, both vertical and horizontal, here and there. In one of these fissures, at 93 feet from the commencement of the limestone, red plastic clay is met with. At 82 feet further on the rock alters to softer material of a pale grey colour with fragments of calcite, apparently a rather dolomitic crinoidal limestone. This broken rock continues for 45 feet, and is succeeded by alternating masses of dark grey limestone and dark grey slates, probably duplicated by folds, for 22 feet. We then encountered dark slates for 174 feet, in which, at 38 and 53 feet from their commencement, irregular beds or lenticles of dark grey limestone were observed. The dark slates are succeeded by red and greenish variegated slates, of a softer and smoother texture, which continue to the foot of the Clock Tower shaft in front of the Royal Theatre. The measurements were taken at the time.

The Bedford Street tunnel, which being at nearly right angles to George Street coincides more or less with the general strike, commences in dark grey slates with calcite veins, similar in character to those in the George Street tunnel, and giving place to red and green variegated slates with glossy surfaces similar to those near the Clock Tower shaft. Their junction crosses the tunnel obliquely at about 200 feet from the Prudential Buildings shaft. It may be a fault.

Messrs. Le Grand and Sutcliff put down a bore in 1890 for Messrs. Polkinghorne at their brewery (Bedford Street). Mr. W. H. Dalton furnished us with the following details—below the surface described as drift for 26 feet, and said by the foreman to consist of yellow clay with stones for 20 feet:—

	Feet.
Marble and limestone	130
Slate	30
Limestone	4
Slate	12
Limestone	16

From the dip, as ascertained by the cores, plotted to scale, Mr. Dalton's section gives the thickness of the several items as follows:—

	Feet.
Marble and limestone	60
Slate	14
Limestone	2
Slate	6
Limestone	7

There is no evidence of the limestone encountered in this well and in the George Street tunnel at the surface, nor is there any feature by which to draw a line for it. Notwithstanding, whether a faulted outcrop or anticline, it does not extend far on the strike. Slates were seen in Westwell Street, slate and volcanic rock at the back of Matthew's Restaurant, slate and a trace of limestone at St. Andrew's Church, and a sewer shaft in Wimpole Street in front of the Free Library was put down to a depth of 55 feet in dark, nearly black, slates. On the west a well was sunk in slates in Frankfort Street, water being obtained at 30 feet.

On the Impacombe and Mount Edgcumbe coast there is reason to think that slates with limestone lenticles mark the dying out of the limestone; but if the upper beds are replaced by slates there is no means of distinguishing them. Moreover the Torpoint rocks are unhesitatingly included in the Upper Devonian, and these prolonged eastward to the Devon shore on their general strike would include the slates on the north of the limestones. Of course the higher beds of the limestone may have passed out into dark or even variegated slates, of fossiliferous character, but there is no proof of this. Characteristic Upper Devonian cyprids have been found near Torpoint and in Antony Park, although no fossils have been found in the variegated slates of Stoke and Mutley on their presumable easterly continuation. The conditions which prevailed during the formation of the Plymouth limestones seem to have been analogous to those which attended the formation of the Dartington limestone in some respects, and to those which prevailed in the Crabs Park district (near Paignton) in others.[1]

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[1] Torquay Memoir (sheet 350) 1903, pp. 73, 87, &c.

In continuing the section left off at Lower Anderton, on the Impacombe coast we find volcanic rocks at Southdown and a development of variegated buff purple and greenish schalstein in faulted juxtaposition to Lower Devonian rocks on the south-west of Southdown, and similar schalstein faulted against slates on the south in the Inswork Brick Pits. These igneous rocks may be on the horizon of the igneous rocks of Mount Batten, Drake's Island, and the Mount Edgcumbe coast, their continuation being broken by faults. On the north of Southdown grey fossiliferous slates form the cliff, and further north calcareous shales and slates, with ferruginous nodular limestone and hard brown lenticles crossing the cleavage, are encountered. Traces of crinoids are plentiful. Grey slates containing *Zaphrentis* come on at the point whence the coast deflects to Sango Point. Grey slates and shales with beds and lenticles of hard dark grey limestone and many intercalated friable decomposed yellow beds then come on, succeeded toward Sango Point by slates with beds of compact grey limestone.

Sango Point is composed of red and greenish slates with occasional small nodules of compact limestone. These beds are suggestive of the *knollen kalk* type of the Upper Devonian.

Following the low coast, from Sango Point east, the section recommences after passing the flat marking the old creek which once completely insulated Southdown.

Toward Penhale bluish and brown, partly calcareous, slates and shales contain beds of hard blue crinoidal limestone and occasional massive beds of limestone. Near this, one of the masses of diabase on the hill north of Penhale comes to the shore. These diabases, and that extending from St. John's Creek to Wolsdon House, may be intrusive sills, but there are traces of volcanic rock in the calcareous slates and shales of St. John's Creek.

The grey and dark grey slates contain lenticles of limestone and decomposed bands. A pale greenish band, probably of volcanic origin, 18 inches thick, is visible in two places at the end of St. John's Lake.

The junction between the grey slates with limestone lenticles and the variegated red and green slates, which form most of the northern shore of St. John's Lake, is probably concealed by Head, shown on the map on the northern shore near the termination of St. John's Lake. There is little to be seen between here and Antony, but from indications of dark slate, in one place welded together with a very small exposure of igneous rock, and in another with a trace of limestone, I think the boundary runs from a shallow permanent well in Antony, at the foot of the churchyard, in a direction E. 15° S., or thereabout, and that it is probably a fault. The termination of the Middle Devonian and its inadequate representation about St. John's would thus be simply accounted for by the bifurcation of the main fault; one branch cutting out the lower beds at or near the Lower Devonian boundary, and the other throwing the higher beds against the variegated slates of the Upper Devonian.

St. Germans District.

The Cawsand fault, judging from the distribution of variegated red and green slates between Earth and Markwell and near Tideford Cross, may cross the Lynher at the railway viaduct and enter the alluvium of the Tiddy west of Markwell, leaving it on the east of Tideford and running thence to Tideford Cross. It may however turn, or send a branch, westward to unite with the Portwrinkle fault at Rosedale.

From Tideford, Cutmere, and Padderbury, southward, dark slates prevail, which from the St. Germans schalstein northward have been included in the Upper Devonian. On the west of Tideford Bridge they contain thin bands and lenticles of limestone. On the north of the St. Germans volcanic band, near its westerly termination, dark grey slates associated with some nearly vertical beds of dark grey limestone are exposed in Treskelly Quarry and contain *Styliola.* In dark slates in St. Germans Park, north of Port Eliot and west of Markwell, *Posidonomya venusta* (Münst.) was noted. In dark slates in Catchfrench Quarry (on the north of the high road north of Catchfrench) *Styliolæ* occur, and these are certainly included in the Upper Devonian. Purple and greenish slates occur here and there between Trerule Foot and St. Germans, but are almost entirely absent between Cutmere and Trerule Foot, where there are several quarries and numerous exposures of grey or dark grey slates, but no traces of fossils were obtained.

The St. Germans volcanic rocks are chiefly grey and green schalstein tuffs weathering rusty brown and buff. A few feet of slate divides the eastern part of the mass near St. Germans Station.

The continuation of the St. Germans volcanic rocks by a series intermingled with slates is visible in the railway cutting between the Tiddy and the Lynher. On the west bank of the Lynher, just south of the railway, grey slates with compact limestone lenticles, producing thickenings in the cleavage planes, occur on the south of the contorted volcanic rock. There is a little purple and green slate by the Tiddy a short distance south of the railway viaduct, so that variegated slates are apparently present on either side of the St. Germans schalstein. This renders the Middle Devonian age of any of the rocks north of the Polbathick valley somewhat doubtful, although it also admits of the possible representation of the upper beds of Middle Devonian, by grey slates locally containing variegated slates indistinguishable from the characteristic Upper Devonian variegated type. The volcanic rocks do not seem to cross the Lynher.

The section from Earth westward shows grey or dark grey slates, occasionally with lenticles of limestone (or friable residues) and with harder bands traversing cleavage. Lenticular bands of limestone, partly crinoidal, occur by the Polbathick Creek, east of Sconner House, and signs of decomposed calcareous matter are visible here and there on either shore.

Grey fossiliferous slates occur within a quarter of a mile south-east and south-west of Polbathick. There are also signs of calcareous material and of crushed fossils in a slate quarry opposite Polbathick, by the road to St. Germans, where the cleavage dip is south at 80°. In the north part of Perdredda Wood near the Portwrinkle fault the slates contain traces of fossils, mostly small, and in a neighbouring quarry (Underways Quarry) some irregular blue slaty limestone is present.

At about a quarter of a mile beyond Catchfrench, near the Portwrinkle fault, papery slates or shales occur. A similar character is exhibited near Landulph. From Catchfrench to Menheniot Station, where we enter on the Liskeard area, the continuity of the Middle Devonian cannot be proved.

Liskeard District.

This is by far the largest area of Middle Devonian rocks in the map. Excepting doubtful rocks toward Pengover Green and Quethiock, it is about twice the area of the Middle Devonian of Plymouth and St. Germans combined.

The prevalent type is argillaceous and fine rather silty sediment with coherent cleavage planes, separating readily at intervals, in floors which give the sections the aspect of thick even-bedded mudstones (see Frontispiece), intersected by joints permitting of the rock being quarried in large prismatic blocks suitable for rough building purposes. Bedding is generally distinguishable by irregular suture-like cracks, here and there traversing the cleavage floors in a zigzag manner, or by an occasional band, of silty or calcareous character, strong enough or sufficiently insoluble to preserve its individuality in spite of compression and distortion. The character of the mudstone where the rather silty type prevails, as between Bosent and Trevelmond, is somewhat suggestive of Lower Devonian.

This type gives place irregularly to grey slates of ordinary character in which the cleavage planes are equally fissile throughout. It is most prevalent between Liskeard and Dobwalls on the north, and St. Keyne and Herodsfoot on the south. The major cleavage planes usually have low dips, and the bedding crosses them at high angles with that gnarled or zigzagged structure so frequent in Devonian rocks.

At Herodscombe Mine, near the Lower Devonian boundary on the east side of the valley at Herodsfoot, the rock presents the appearance of a dense dark grey mudstone with rather paler interbanding, denoting cleavage and exhibiting parallelism to the major cleavage planes along which it splits in slabs about half an inch or so thick. The parallel banding is crossed obliquely by a fine structure like undeveloped secondary cleavage, which is shown by the alignment of occasional small fossil traces to be bedding. At Herodsfoot Mine, on the opposite side of the valley, the tips are of ordinary dark slates.

Near Liggars, at one mile N.17° E. from Herodsfoot Church, blue brown-weathered fossiliferous slaty mudstones are exposed in a quarry, the bedding being apparently more or less vertical with undulations. On the east side of the valley, about 660 yards north-west of this quarry, dark slates with traces of fossils give north and south dips in schistosity. At about 440 yards north of this, about 300 yards north-west of Higher Scawn, there is a quarry in brown-banded fossiliferous mudstone with planes dipping southward at 15° to 20°, and with signs of bedding accentuated by quartz veins. The fossils include trilobites, brachiopods and crinoids. On the east side of Trevelmond, by the lane, grey and drab slates contain *Aulopora* or *Cladochonus*, a small *Zaphrentis*, and fragments of trilobites, apparently *Phacops* (*Cryphæus*) *punctatus* (Stein.). The fossils in both these exposures are similar to those in the slates of Elburton, east of Plymstock (Sheet 349), near the southern border of the Plymouth limestone.

Mr. Giles considered the fossiliferous slates of Trevelmond identical with those at Bodmin.[1] In the lane from Trevelmond to St. Pinnock tough brown-weathered slates, with schistosity varying from horizontal planes to low southerly inclinations, are intersected by irregular crumpled-looking cracks, evidently gnarled bedding planes from which calcareous or other soluble material had been dissolved. There are traces of fossils. Between Trevelmond and Dobwalls, south of the railway, the mudstones exhibit fine pale banding.

The slates or mudstones are locally stained reddish near Dobwalls and south of St. Pinnock. The argillaceous slates and mudstones give place to dark slates of a more pronounced type beyond Coldwind and Tuelmenna, and these have been extensively quarried in the adjacent map (347) south of St. Neots. Whether they belong to the uppermost horizons of the Middle, or to the basement beds of the Upper Devonian is uncertain.

The East Looe valley presents many good exposures. Between Lametton Mill and Killagorrick grey slates prevail, but further north the prismatic splitting mudstones are typically exposed in quarries near Gormellick, Trussel Bridge, and in the wooded tributary valleys south of Moorswater.

In a quarry south of Lamellion, the mudstone yields large blocks.

Mr. Giles[2] records the discovery of *Phacops arachnoides* (according to McCoy), a large *Petraia*, *Pleuodictyum problematicum*, *Receptaculites neptuni* (according to McCoy), *Aulopora repens* (?), and of *Spirifer*, *Orthis*, and *Leptæna* in argillaceous beds, consisting of alternating soft light-coloured, and coarse bluish, bands, dipping with and across cleavage near Trussel Bridge. This locality is probably the old quarry by the road on the west of Trussel Bridge. Near the west end of Slip Wood blue mudstones have been quarried, yielding large flat blocks; bedding is shown by brown vertically contorted fossiliferous bands. Vertically zigzagged and curved bedding is also shown in quarries on the east side of the valley, at 280 yards south, and 550 yeards north of Trussel Bridge, respectively. The Frontispiece is a photograph of a quarry a quarter of a mile west of Lamellion, in which grey drab-weathered mudstones exhibit suture-like vertically curved bedding cracks traversing planes with a southerly dip of 15°. Both are crossed by joint cracks inclining southward at about 60°.

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[1] *Trans Roy. Geol Soc. Corn.*, vol. vii., p. 98.

[2] *Ibid.*, p. 169.

The extension of the Looe Railway to Liskeard yielded good exposures in cuttings south of the viaduct (where it passes under the Great Western Railway). Dark slates here form a more or less calcareous series with a pronounced interbanding of limestone and decomposed friable residues. The cleavage planes are in part nearly horizontal, and the dip, shown by stripe or crinkled lines of fracture, crosses them in highly inclined undulations. Where the signs of bedding are absent the cleavage sometimes simulates thin horizontal bedding.

In an old quarry by the high road to Liskeard, north-east of Bolitho, vertically contorted bedding is shown to cross the cleavage of slates. East of Bolitho, by the Great Western Railway at Cartuther Viaduct, and south of Trethawle, grey slaty mudstones have been quarried, yielding in some places long blocks and splintery masses, in others rectangular blocks.

At half a mile south-west of Trethawle splintery-fractured fossiliferous slaty rock has been quarried, and mid-way between this and the volcanic patches on the north, dense finely laminated slaty mudstones are exposed in a quarry. The larger patches of volcanic rock near this are chiefly schalsteins and the smaller patches to the east and west are vesicular volcanic rocks associated with slates.

In the railway cutting due south of Bolitho a small patch of igneous rock is overlain by altered slates. The two small patches on the south and a lesser one, near by, on the north, may be intrusive, also the masses at and near Cartuther and south of Trethawle. The bands of volcanic rock near the Clicker Tor picrite mass on the north-west to beyond Treviddo, seem to have been fine tuffs and vesicular lavas. They may be the same series (shifted by fault) as the tuffs, schalsteins and vesicular igneous rocks in the dark slates north of Menheniot Station, and east toward Coldrenick, and the connection of both with the schalsteins and vesicular igneous rocks near Trethawle is very probable.

It would be out of place here to enter into the relations of the volcanic rocks, but this line of igneous rocks occurring just on the north side of the direction which, if prolonged, the Portwrinkle fault should take is suggestive, and the absence of volcanic rocks west of the East Looe valley is suggestive, either of the cutting out of a volcanic horizon by fault, or of the western border of a region of vulcanicity. In either case the volcanic materials would appear, if Middle Devonian, to be very high in that group. In the some category we may include the igneous rocks running through Liskeard, which may be intrusive sills, and perhaps those between Stony Bridge and Roseland.

Roseland Quarry is on the east side of the Seaton valley west of Tregrill. It has been described by Peach[1] and Giles.[2] The latter gives the descending section as, soft brownish slates with very few fossils upon about three feet of argillaceous limestone containing *Trilobites, Orthoceratites, Bellerophon, Turbinolopsis, Pleurodictyum problematicum* and crinoids, upon hard blue slates worked for roofing and flooring flags. The dip is said to be southerly at from 6° to 20°, and cleavage south at 36° to 40°. Most of the beds contain iron pyrites; the slate beds are traversed by minute veins of lead-bearing quartz and contain calcareous concretions.

Mr. Fox showed me specimens of dark slate with numerous *Styliolæ* which he obtained from this quarry, so the rocks are either altogether Upper Devonian, or only Middle Devonian from the limestone downward.

Opposite the quarry (at Cartuther Mill), on the south of a mass of proterbase, the slates are in part converted into white-coated hornstone. There are thin bands of tuff in them between this and Tregrill. Not far north of the igneous mass blue slates are shown with a south cleavage dip of 24°, and appearances of bedding inclining east at 5°. This dip accords with the irregular northerly strike of decomposed igneous rocks north of Roseland Quarry.

By the high road to Liskeard, north of Bolitho, a well was sunk through slate to a depth of 54 feet when rock similar to that of Clicker Tor was said to be encountered. This spot, Maudlin, is on the site of an Hospital for Leprosy.

A mass of igneous rock is exposed in a quarry between Stony Bridge and the (Bodgara) Mill by the Seaton valley east of Liskeard; dark slates associated with two masses of finely crystalline limestone either abut against, or are in vertically plicated junction with, it.

On the north and west of Liskeard the slates and slaty mudstones are more or less argillaceous and weather buff or rusty brown. On the south-east side of Trembraze *Pleurodictyum problematicum* (Goldf.) was noticed in a quarry of argillaceous slates with low southerly dipping cleavage planes and vertically undulating bedding. There are many quarries and exposures, on either side of the Seaton valley, for a mile or more above Stony Bridge, which display slates and mudstones often banded with, or showing signs of the decomposition of, calcareous material. Giles noticed carbonate of lime in the slates at Stony Bridge, and obtained *Trilobites, Turbinolopsis* and a probable *Spirifer*; he refers to a flexure and to the jaspideous texture of the slates below the fossil horizon, rendering them hard enough to be used for roadstone.

Salter mentions the occurrence of *Phacops latifrons* in slates with *Pleurodictyum* near Liskeard and of *Phacops* (*Cryphæus*) *punctatus* in the slates of Liskeard.[3]

At the north margin of the map the rocks are altered, being just within the contact zone; they resemble platy rocks at Ivybridge, and may be Middle or Upper Devonian.

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[1] Peach. *Trans. Roy. Geol. Soc. Corn.*, vol. vi., p. 19.

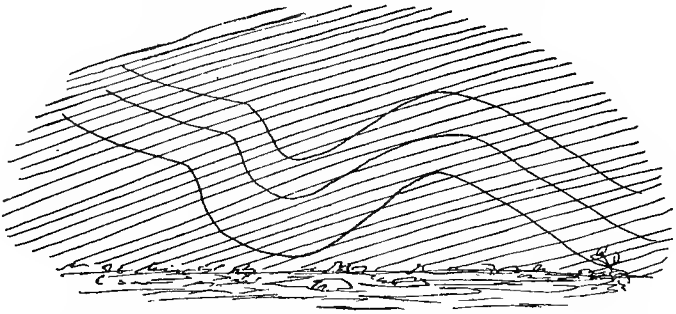
[2] Giles. *Ibid.*, vol. vii., pp. 93—97.

[3] 'A Monograph of British Trilobites.' *Pal. Soc.*, 1861, pp. 20, 59 and 60.

Between Merrymeet and Venton House argillaceous mudstones, broken into bed-like masses by nearly horizontal major cleavage planes, show vertically curved, or zigzagged, bedding in suture-like cracks and brown seams. Similar rocks with low southerly cleavage dip are exposed between Merrymeet and Penhawger. Near Quethiock the slates betray no definite character. South of Merrymeet the mine tips are all in dark slate, stated by Mr. J. H. Collins to be the same as that at Herodsfoot. At Trevartha, south of Pengover Green, grey slates with low schistosity dips are traversed by several thin bands of limestone.

A mile and a half east of Trevartha, a quarry at Hepwell Bridge (Fig. 9) shows bluish, brown-weathered, slates, with cleavage planes dipping at a low angle southward, irregularly traversed by bedding cracks accompanied by brown films.

FIG. 9.—*Quarry at Hepwell Bridge.*



On the east side of the valley between Trecorme and Trewoodgate the road cutting exhibits dark slates with lenticular beds of hard brown-weathered limestone.

The foregoing, although the rocks have been coloured as Upper Devonian on the map, are somewhat suggestive of a complex anticline of Middle Devonian rocks in the Upper Devonian districts east of Liskeard. In Kilquite Quarries (on the east of, and near to, Tilland) thin limestone bands occur impersistently in the dark slates in places. This is not conclusive evidence of Middle Devonian, because limestone bands and nodules are characteristic of some well-known types of the Frasnian or lower beds of the Upper Devonian.

The occurrences of *Pleurodictyum* in the slates of Trembraze and in Roseland Quarry, described by Giles, west of Tregrill, are included in the Middle Devonian on evidence which may appear slender, but no indications of such fossils have been met with in the numerous localities (except in Roseland Quarry) where cyprids and *Styliolæ* have been found, and these localities have not yet been found to extend to the westward of the Seaton valley. Again, the volcanic rocks practically disappear in the same direction. There is, therefore, some ground for admitting the probability of the extension of an anticline of Middle Devonian toward Quethwick.

As regards the local limestone bands and lenticles which have been mentioned in this chapter as possible evidence of a complex anticlinal of Middle Devonian amongst Upper Devonian slates and volcanic rocks, and the calcareous materials at Sango Point on the south of St. John's Lake, and west of Tideford Bridge; in the absence of fossil evidence these might with equal if not greater propriety be included in the Upper Devonian. Their inclusion in this chapter is on no better grounds than adherence to the trite principle of giving preference to the older rock in doubtful cases.

IGNEOUS ROCKS IN THE MIDDLE DEVONIAN.

Through decomposition and consequent assimilation in character to decomposed calcareous materials many of the thin bands and seams of tuff associated with the Middle Devonian slates have no doubt escaped detection. Notwithstanding this, there is every reason to conclude that the tuffs and schalsteins which form so distinctive a feature in the Middle Devonian from Plymouth eastward become less abundant in that series westward, and are not represented in the area west and south-west of Liskeard, although feebly evidenced in proximity to a fault in the adjacent map (Sheet 347). How far this may be due to the cutting out of the rocks above the Eifelian slates (which are, as a rule, unaccompanied by contemporaneous volcanic rocks) by the prolongation of the Portwrinkle fault through the Liskeard area it is not possible to say. In the St. Germans district there is a strong probability of a bifurcation of the Portwrinkle fault from Rosedale along the Polbathick valley to the Cawsand fault near Earth. If this is the case the volcanic rocks of St. Germans would probably belong to the Upper Devonian, and the Middle Devonian slates would be almost cut out.

The spilites in George Street sewer and at Raglan Barracks are provisionally included in the Upper Devonian. The contemporaneous igneous rocks in the Middle Devonian of sufficient importance to be shown on the map are: In the Plymouth district—the volcanic rocks of Mount Batten, of Drake's Island, of Southdown, and of Inswork, all of which are about the same date, and a mass of volcanic rock in plicated and irregular association with the slates, on the coast east of Mount Edgecumbe House, which may be somewhat lower in the series. In the Liskeard district—the patches of schalstein near Trethawlè, south of Liskeard, and possibly volcanic bands between these and Clicker Tor. The igneous rocks near Liskeard may, if volcanic, belong also to the Middle Devonian. The Mount Batten rock is a "ferruginous volcanic ash," according to Worth.[1] White dolomitic concretions veined with quartz occur in this rock.

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[1] *Trans. Devon Assoc.*, 1887, vol. xix., pp. 486, 487.

Worth called the Drake's Island volcanic rock a "chloritic tufaceous clay slate."

Dr. Flett describes the Drake's Island rock as "greenish-yellow, sheared and brecciated igneous rock, filled with chlorite, limonite and secondary quartz, but containing unusually little calcite. It has been fine-grained, but in consequence of the shearing and decomposition its original structures are nearly effaced."

Whether lavas or tuffs, the Drake's Island rocks are schalsteins and most certainly contemporaneous. The diabase patches north of Penhale and St. John's, terminating at Wolsdon House, are probably intrusive dykes or sills. In the Liskeard district, near Pendean on the west of Liskeard, decomposed brown igneous rock resting on indurated grey slate is shown in a bye-lane. In another place the igneous rock occupies a pipe or synclinal pocket in the slate. The evidence is not sufficient to establish the contemporaneous character of the igneous rock.

The igneous rocks near Gormellick and Trethawle consist of schalsteins resembling sheared felspathic tuffs and of highly vesicular lava analogous to that of Henn Point; they seem to be above the surrounding slates. An interesting section is furnished by a quarry on the north of Bodgara Mill (the mill in the Seaton valley east of Liskeard). Here blackish slates with two masses of sub-crystalline limestone (possibly Upper Devonian) are probably in vertically contorted junction with hard grey igneous rock, which may be either intrusive or contemporaneous. The igneous rocks are regarded by Dr. Flett as "of a different type from the vesicular lavas as they are more coarsely crystalline, and though they contain lenticles of calcite, they do not show rounded steam cavities. Their principal component is plagioclase felspar in crystals up to ½ mm. in diameter. These are embedded in chlorite and calcite which form irregular streaks between them. Iron oxides, mostly ilmenite weathering to leucoxene, are also common. The affinities of these rocks are with the diabases. They are distinctly sheared though not greatly, and are veined with chlorite and calcite." This may be the rock described by Phillips[1] at half a mile west of Trewolland. As regards the contemporaneous volcanic rocks in Sheet 348 it may be confidently stated that the period they extend over began during stages in the formation of the Plymouth limestone and continued with increased intensity through the earlier stages of the Upper Devonian, but in a restricted area. Whether amongst the volcanic rocks of the Upper Devonian area there are anticlines of Middle Devonian volcanic rocks or not is almost wholly dependent on the recognition of Middle Devonian sediments, proofs of the occurrence of which have not been obtained.

The following notes are by Dr. Flett:—

The igneous rocks in the Middle Devonian of this sheet have all a great similarity in general character and may be conveniently grouped together under the name of schalsteins. In their microscopic features they do not differ essentially from the better preserved and more numerous volcanic rocks which occur in the Upper Devonian of this sheet (see p. 94). In the hand specimens they are various shades of green ranging from dark tints to a pale grey green according to the amount of chlorite and calcite they contain. A few have a fairly massive appearance but most are schistose, and in some cases a pronounced thin foliation has developed. Where they are vesicular they show rounded white spots consisting of calcite, and these are flattened out in the more sheared specimens till they form elliptical or elongated lenticles parallel to the schistosity of the rock. They are all soft and much decomposed, but in the last stages of degeneration they are converted into creamy, pale brown or rusty coloured masses.

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[1] *Quart. Journ. Geol. Soc.*, 1878, p. 488.

That they were originally basic igneous rocks is perfectly clear both from their relations in the field and from their structure in microscopic section. The abundance of vesicles filled with calcite is one of their most obvious peculiarities and leads to the assumption that they are either lavas or tuffs which are composed largely of spongy lapilli. In either case they are contemporaneous, interbedded igneous rocks. The tuffs, when least sheared, often preserve their fragmental structure, and the scoriaceous lapilli, though drawn out, bent and flattened by pressure, are visible in the sections separated by a matrix of crystalline grains of calcite, with chlorite, argillaceous matter, original and secondary quartz, limonite and other decomposition products. Grains of sphene produced by the weathering of titaniferous iron oxides, and small, sharply crystallised, rhombohedra of dolomite appear also in many of the sections. Any considerable percentage of argillaceous or arenaceous sedimentary matter is rarely present.

The spongy igneous rocks consist of plagioclase felspar, chlorite and other secondary products after pyroxene, and iron oxides. It is no longer possible to make certain of the original presence of olivine; definite pseudomorphs after this mineral have never been observed. A fine devitrified or minutely crystalline groundmass is abundant, especially in the most vesicular specimens, but its characters cannot be satisfactorily studied in consequence of the decomposition of the rock and the infiltration of calcite and other secondary minerals. Fluxion structure is very common and often very perfect; the larger felspars lie with their long axes parallel or form undulating streams while the smaller elongated or acicular felspars wind around them. The rocks are in many cases porphyritic, though the phenocrysts are not large; they belong usually to plagioclase felspar, which, when determinable, has the composition of oligoclase. It is often replaced by calcite, kaolin, mica and quartz and is permeated by chlorite from the surrounding rock. The augite has proved even more susceptible to decomposition than the felspar; only very rarely can fresh fragments of it be discerned as by far the greater part has passed into chlorite, calcite and finely granular sphene. Pyrites, magnetite, ilmenite and leucoxene, together with a small amount of apatite, are the remaining ingredients of these rocks.

In all the sections the evidence of pressure and crushing is conspicuous, but the metamorphism is never of an advanced type. For this reason, among others, the pale green hornblende so abundant in the igneous rocks known as greenstones in western Cornwall is not observed in the Plymouth schalsteins. Neither does epidote develop, at any rate in any quantity. The more spongy rocks show the effects of pressure first in the material filling their vesicles; the calcite, which is coarsely crystalline, yields along its crystalline glide-planes, and its cleavage and twinning often exhibit curvature and contortion. The yielding of the contents of the amygdaloidal cavities is accompanied by a distortion of the rock matrix. The felspars are twisted and bent; frequently they are fractured and the fragments drawn apart. The chlorite no longer retains the form of the original augite, but passes into elongated or sinuous lenticles. When flattening is extreme the whole rock becomes schistose and all its elements assume a parallel orientation. Still, as remarked above, the changes are limited in degree, and there is no close approach in minerals or structure to the true crystalline schists. In fact when the rocks are not badly weathered their igneous structures are usually sufficiently well preserved to allow a fairly clear conception to be formed as regards their original nature. Dr. Teall[1] has remarked on the complete similarity of these rocks in all essentials to the igneous masses belonging to the same system in the Harz, Thuringia, Westphalia, and the Ardennes.

The Drake's Island rock (4322), described by Worth, is probably a very rotten basic lava or tuff. A finely vesicular crushed tuff was obtained in the sewer under George Street (4309), Plymouth (Pl. 4, fig. 2), amygdaloidal basic rocks (probably lavas) occur near Hartley Reservoir (Pl. 4, fig. 3) (4307) and at the Raglan Barracks (4310), Plymouth. The Trethawle rock (4570, 4571) is greatly sheared and utterly decomposed, so that it is a schistose aggregate of calcite, chlorite, limonite and quartz, but there can be no doubt of its igneous origin. Near St. Germans (W.N.W. of Fairfield House), there is a much crushed schistose green calcareous tuff (4569). The specimens from the quarry near Bodgara Mill (4320, 4321) are more coarsely crystalline and not vesicular; there is some reason to believe that this is a crushed intrusive mass.

J. S. Flett.

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[1] Teall, J. J. H., 'British Petrography,' p. 234, (1888).

CHAPTER IV.

UPPER DEVONIAN.

General Notes.—Types, Fossils.

In the Torquay and Newton Abbot limestone area the occurrence of *Rhynchonella cuboides* (J. de C. Sow.) with *Stringocephalus* in the limestones of Lummaton and Wolborough (with which the upper part of the Plymouth limestone must be correlated) renders the separation of the Upper from Middle Devonian by these leading Continental fossils impossible. The most satisfactory boundary that can be obtained is in those cases where shaly Upper Devonian Goniatite limestones, or their slaty representatives with the Büdesheim fauna consisting of small *Goniatites*, *Bactrites*, and *Buchiola retrostriata* (v. Buch.) are in contact with the massive reef limestones, as at Petitor, Ilsham, and Lower Dunscombe. In Sheet 348 these characteristic types have not been found in contact with the Plymouth limestone, although badly preserved but unmistakable traces of the Büdesheim fauna have been discovered near Warren Point on the Devon shore of the Tamar and between Ince Castle and Earth on the Lynher estuary in Cornwall in the slate districts, four miles north and west-north-west of the Plymouth limestone respectively.

The relation of the limestone to the slates on its northern border may best be explained on the assumption that the reef growth did not extend northward, and that muddy sedimentation on its margin would take place slowly, and considerably below the level of coral growth. Thus, when buried beneath muddy sediments, the successive coral growths would end abruptly against materials subsequently deposited. Subsequent movements would tend still further to obscure the stratigraphical relations of limestone and slates. This explanation would equally apply to the northern border of the Newton Abbot limestones.

The occurrence of red and green slates in the Middle Devonian is local and exceptional; in the Upper Devonian, on the other hand, they are characteristically but irregularly developed, pale green or greenish-grey tints being on the whole most prevalent. The deep red green-banded slates of Mutley have their counterparts in the slates of Pentire Haven, in North Cornwall, as also in the slates of Goodrington, Saltern Cove, Petitor, Highweek, and elsewhere in the Torquay and Newton Abbot area.

The Mutley and Pentire variegated slates are very similar in colour and variegation to the Dartmouth slates of the Talland coast, so that without any clue to the Devonian succession it is not surprising that De la Beche should have correlated the variegated Upper Devonian slates of Pentire with the variegated Lower Devonian slates of Watergate Bay.

In 1888 in investigating the South Western Railway cuttings between Devonport and Tavistock I placed[1] the purple-red and green slates of the Plymouth area in the lower part of the Upper Devonian. This correlation was established by my discovery of the characteristic cyprids in 1893[2] at Torpoint, &c., and by Mr. Fox's discovery of the Büdesheim fauna in North Cornwall in 1894,[3] both discoveries being announced in his Presidential address to the Royal Geological Society of Cornwall in the latter year. By Mr. Fox's researches at Trevone and in the Padstow estuary, and by my independent work in Sheet 348, the local association of beds of limestone in dark slates containing *Styliola* has been proved, so that the bands of limestone that occur in the slates of Botus Fleming must be included in the Upper Devonian, except perhaps the coralline limestone of Nail Point (near Landulph), which might represent the top of the Middle, although there is very little doubt that *Buchiola retrostriata* occurs in the dark slates to the north of it.

In the boring put down to a depth of 412 feet by Messrs. Isler and Co. for the Saltash Corporation, on the west of the town, no signs of limestone were encountered, the specimens obtained for investigation being powdered grey slate with quartz veins in places. The cores were unfortunately destroyed, and the charts of this sinking and of the well at Messrs. Vaughan and Co.'s Saltash Brewery, sunk to a depth of 174 feet, only mention slates with 'stone' and 'hard blue rock with white crystallized veins' which may be andesitic basalts.[4] There is therefore no evidence that the Plymouth limestone mass extended northward, and it is highly probable that its horizon is to some extent represented by dark slates such as those which separate the limestones in the George Street sewer tunnel from the variegated slates on either side of them. Without fossil evidence it is not possible to distinguish dark slates which may represent the upper stages of the limestone from dark slates which partly represent the lower stages of the Upper Devonian.

The Upper Devonian rocks are slates which, through accidental coincidence of cleavage with bedding and where interbedding with limestone bands has protected them, locally exhibit the character of shales. Where the planes of lamination or cleavage are not fissile they assume the aspect of argillaceous mudstones.

The greenish, purple and green, and grey slates are all more or less plentifully sprinkled with small particles of white mica, and both the green and dark grey slates where sheared often present a sericitic aspect. The slates associated in the more or less calcareous horizons (as in the Landulph coast) often weather to a pale brownish tint and exhibit a somewhat pulverulent aspect. This is equally noticeable in the Port-hilley and Rock coast in the Camel estuary, and the surfaces are mottled with tiny dots and specks, amongst which *Styliolæ* are often recognisable. Slates of this type are visible amongst the variegated slates of Warren Point and between Earth and Ince Castle.

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[1] *Trans. Devon. Assoc.*, 1889, vol. xxi., p. 450. See also *Quart. Journ. Geol. Soc.*, 1890, vol. xlvi., p. 512; and *Trans. Roy. Geol. Soc. Corn.*, 1891, pp. 48, 49.

[2] 'Report of the Director-General of the Geological Survey for 1893.'

[3] *Trans. Roy. Geol. Soc. Corn.*, 1894.

[4] Fuller details of this boring are given on pp. 131, 132.

Near Trewint (near Menheniot) by the road to Hepwell Bridge, and between Coombe and Penpoll argillaceous mudstones with white and grey banding occur. The rocks west of Quethiock and north of Tregondale are in places similar in type to banded rock which occurs at Herodscombe Mine, and in the absence of any recognizable fossils we may here entertain the probability of a plicated association of Upper and Middle Devonian strata.

Association with Volcanic Rocks.

The cutting of the South Western Railway when first opened[1] displayed the characters of the slates and their association with contemporaneous and intrusive rocks in the district north of Plymouth much better than they do now.

The mouth of the tunnel at Devonport South Western Railway Station has been excavated in purple green-banded slates. After penetrating a mass of dark grey slates, the tunnel terminates in green and purple slates. On crossing the intervening valley Ford Cutting commences in grey slates faulted in one place and succeeded near Ford Station by contemporaneous igneous rocks consisting of schalstein-tuffs, breccia, and vesicular andesitic basalt. These are probably faulted in two places where slates occur. They occupy the cuttings for about 220 yards, dipping southward, and are succeeded on the north by dark grey slates with quartz veins and ferruginous staining at the joints. At commencement of the next cutting the grey slates give place to purple and greenish slates, the latter tint predominating toward Camelshead Bridge.

After crossing Camelshead Bridge the next cutting exhibits dark grey slates with a mass of felsitic rock, cleaved in thick slabs and apparently passing into tuffs similar to those near Ford Station. This rock is exposed in a quarry by the adjacent high road on the west. It is described by Dr. Flett as follows:—"This pale green and brown felspathic rock is evidently sheared, and in the microscopic section shows many broken crystals of plagioclase felspar in a more or less crushed matrix, in which much fine scaly sericitic mica has developed. Calcite and iron oxides are present also, and some specimens are stained with diffused limonite. Quartz occurs in small quantity, being absent from most of the rock. This is a breccia of igneous material, probably a fine, highly felspathic crystalline tuff, differing slightly in composition and appearance from the majority of the contemporaneous igneous rocks of the schalstein group, but belonging to the same series." The igneous rocks occur in several places in the slates for a distance of about 190 yards. They are probably repeated by plication, and their continuation toward Bull Point, owing to admixture with slate, necessitates the indication on the map of much more igneous rock than is really present. This is also the case on the east, where only the northernmost exposure can be traced from the cutting. The next cutting is encountered near Saltash Passage south of the commencement of the Royal Albert Bridge. The cutting is in dark slates, almost black, in which igneous rock is seen in several places occurring as in the accompanying rough sketch (Fig. 10). There are four bosses of vesicular grey igneous rock (*a b c d*) which may be the same mass repeated. At *e* a pale grey rock, probably felsitic (described by Worth[1] as "a much altered amygdaloidal lava" veined by steatite) appears, and at *f* a felsite or felstone, with slabby structure as in the cutting last described. The igneous rock at *g* may be a lower band. There are at least three faults or thrusts (T T T) in the section, which was taken during the construction of the line in 1888. The felstone in this section is described by Worth as "a typical tuff, with fragments of lava and broken crystals in a matrix of fine sediment."

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[1] Described by Worth, *Trans. Devon. Assoc.*, 1889, vol. xxi., pp. 261–288; Ussher, *Ibid.*, pp. 437–451

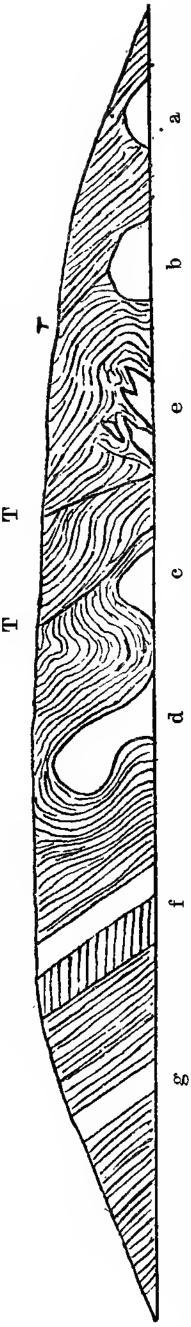

FIG. 10.—*Railway-cutting south of the Royal Albert Bridge.*

Hard greenstone was found in the channel under the central pier of the Royal Albert Bridge. It may be a continuation of the igneous rock, exposed at about 80 yards north of the bridge, on the Devon shore (which is described by Worth as an ashy tuff) with a similar rock on the Saltash shore.[2]

In the railway cutting north of the Albert Bridge, greenish-grey mudstones, broken by slaty cleavage but with pronounced indications of thick contorted beds, are seen to be much indurated in contact with an intrusive mass of dolerite. Further north an intrusive mass of proterobase, scarcely seen in the cutting, is well exposed in the foreshore. These rocks exhibit spheroidal structure. "The dolerite is largely felspathic, and in its unweathered portions prominently crystalline. It contains plagioclase felspars, mica, augite, viridite, apatite, and ilmenite, and has been described by Mr. Teall as an 'ophitic mica-bearing diabase containing much apatite'."[1] Worth considered that the "hard, compact, closely-jointed olive grey slates" in this cutting had been for the most part originally "very fine grained volcanic dust," and detected in them "traces of tufaceous bands of finely vesicular lava flows." Somewhat similar types in North Cornwall, near Pentire, and in the Newton Abbot area may perhaps owe their more solid or massive character to an admixture such as that suggested. The next cutting is in green and purple slates, just south of Tamerton Creek; these show signs of crushing and disturbance marked by quartz veins and contrary inclinations in cleavage planes. The cutting between Tamerton Creek and the Tavy is in grey and drab slates, with a two-foot band of decomposed igneous rock near the Tavy.

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[1] Worth, *Trans. Devon. Assoc.*, 1889, vol. xxi., pp. 280, 281; Ussher, *Ibid.* pp. 439, 440.

[2] *Ibid.*, 1887, vol. xix., p. 476.

Distribution of colouring matter.

Worth suggested a six-fold repetition of the strata between the Tavy and Plymouth, based on the recurrence of purple slates.[2]

A general separation between the purple and green and the grey slates can be made, but this does not exclude local occurrences of either in the chief developments of the other, and is subject to the caprices of oxidation leading to the partial or complete absence of the purple tints which are of much more restricted and irregular occurrence than the green.

Purple and green slates prevail from the Plymouth limestone northward to Ford and Mutley, but dark grey slates occur at Devonport Great Western Railway Station, speedily disappearing eastward, and perhaps represented westward by grey slates amongst the variegated slates of Antony Park and Torpoint. Purple and green slates occur at Camelshead Bridge and the Naval Barracks, from thence eastward to Prospect Hall, and to a small extent at Pounds; they are bounded by the grey slates in which the volcanic rocks of Hartley Reservoir, Thornhill, Ford, and St. Budeaux occur. These grey slates run through St. Stephens to Tideford Cross; they are bounded on the north by purple and green slates between St. Budeaux and Tamerton Foliott, and on the south by similar variegated slates between Antony Ferry and Markwell.

The variegated slates on the north extend westward through Carkeel to Notter, where they become associated with volcanic rocks, toward Landrake, Trewandra, and Blunts; the same igneous rocks continuing in association with grey slates westward. The purple and green slates run westward from Brightor and Tideford to the vicinity of the Seaton Valley, in irregular masses, to the west of Menheniot and south of Trenodden and Doddycross.

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[1] *Ibid.*, 1889, vol. xxi., p. 280.

[2] *Ibid.*, p. 288.

The variegated slates of Carkeel are bounded on the north by dark slates, which, with beds and lenticles of limestone (often decomposed to friable residues), are seen on the shores of Tamerton Creek, near Budshead, and extend from the Landulph coast through Botus Fleming for nearly three miles westward. The variegated slates of Carkeel pass round this dark slate tract by Notter to Hatt and Cargreen. Nail Point at the entrance to Kingsmill Lake is composed of irregular slaty grey limestone with contorted bedding planes, made up chiefly of corals, amongst which *Alveolites* and *Stromatopora* make solid lumps of paler colour contrasting with the broken rock made up of ill-preserved smaller corals. This mass of limestone was considered to be Middle Devonian on my first visit in 1888, when a coral (probably *Alveolites* penetrated by *Caunopora* tubes) was thought to be *Heliolites porosus*.[1] It is faulted on the south against green, buff, and purple slates, and is succeeded on the north by dark slates, partly calcareous, and irregularly associated with limestone. These slates often weather to rusty brown, and show numerous traces of small organisms, including *Styliola*.

Further to the north, dark slates of calcareous aspect prevail, and these are faulted against purple and green slates (in which *Entomis* was found) at 220 yards from Weir Point.

The low cliffs bordering the marsh at Landulph show calcareous slates, and slates with friable nodules and occasional beds of hard brown-weathered limestone. Further west the north shore of Kingsmill Lake exhibits grey slates, with nodules of compact limestone and friable residues. Beds of hard dark blue limestone (probably impersistent) are present at about 260 yards from the marsh, the slates with decomposed nodules being again visible opposite Botus Fleming Creek.

At Moditonham Quay dark grey and buff slates, with *Styliola*, are exposed, and following up the Kingsmill Creek we encounter a little purple and green slate, succeeded by dark slates containing a few lenticles of limestone, and white bands indicating an anticline in the bedding. Nearly opposite this, on the east, a band of igneous rock is exposed, running for 300 yards in a north-easterly direction, but not distinguished on the west shore. Further north, greenish and buff slates, with ferruginous concretionary bands and nodules, display a tendency to gnarling on the east shore. The creek then bends sharply to the west, the north shore being composed of purple and green slates. Near the southern shore there is a quarry in 15 to 20 feet of blue limestone, seemingly an impersistent development in the slates, and dipping in a south-easterly direction. Limestone is again visible in a pit about 80 yards south of the northern border of the dark slates, on the west side of the road from Kings Mill to Botus Fleming.

Brown and buff friable bands and seams, and occasional traces of limestone, occur in the slates of Botus Fleming. On the southern shore of Tamerton Creek dark slates (with *Styliola* at about 440 yards west of Budshead), contain in places bands and lenticles of compact blue limestone, and of friable residues. Up the wooded shore of the creek on the east of Budshead, hard blue limestone lenticles occur in dark grey and buff slates, between which and the purple and green slates no line of separation can be drawn. *Goniatites* and markings suggestive of *Styliola* have been obtained in greenish and buff-grey slates, associated with purple slates, near Warren Point by the Tamar.

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[1] *Trans. Devon Assoc.*, 1889, vol. xxi., p. 440.

Between Beer Ferrers Station and the Tavy the principal South-Western Railway-cutting as described by Worth[1]

"begins in drab slate and passes to hard blue massive slate, with quartz veins and segregations, some highly crystalline, also calcite. Much of the rock here is thick-bedded and imperfectly cleaved. There is great contortion and some faulting. At no point of the line . . . is disturbance without the actual presence of a disturbing cause so strongly marked. . . . The cutting passes out in ordinary drab slate."

The next cutting on the south is shallow, and exhibits loose drab slate. To the south of this, the shores and bottom of the Tavy were proved to consist of purplish slates "well jointed and closely cleaved, the cleavage faces being finely wrinkled."

The purple variegation is almost entirely absent from the pale grey and green slates and mudstones north of a line connecting Looseleigh House, Tamerton Foliott, and Warleigh Barton, in Devon, and prolonged in Cornwall from Cargreen to Quethiock; but, although this might be in part due to the cutting out of variegated beds on the north of the Botus Fleming anticline by faults, the occurrence of purple slates beneath the St. Mellion outlier, near Polborder, and near Ludcott (near Trebeigh Wood), makes it much more probable that the same horizons in which variegation so strongly prevails on the south are represented by greenish slates on the north, which through the absence of determining causes were seldom peroxidated, or if peroxidated were subsequently largely deoxidized.

Fossil Localities.

The occurrence of *Styliola* and of *Posidonomya venusta* (Münst.) in dark slates in St. Germans Park, and of the former fossil in a quarry near Catchfrench (south-east of Menheniot), in Roseland Quarry (near Tregrill), and near Botus Fleming, justifies the inclusion of the dark slates north of the Plymouth limestone of St. Germans and east of Roseland slate quarry in the Upper Devonian. It is very probable that the calcareous beds and lenticles by St. John's Lake near Sango Point, between Trecorme and Trewoodgate, and in Kilquite Quarries (described in the foregoing chapter) may correspond to the limestones of the Botus Fleming valley, and of the Padstow Estuary; but as no fossils have been found in them, or in the associated slates, they have been very doubtfully ascribed to the Middle Devonian. The possible representation of the Landulph limestone by dark limestone in George Street sewer tunnel is also suggested. The only places where signs of the Büdesheim fauna have been met with are as follows:—Devon shore of River Tamar, at 110 yards south of Warren Point, small *Goniatites* in greenish and grey slates associated with purple slates apparently containing *Styliola*. The grey slates of Landulph associated with limestones contain *Styliola* in abundance (possibly also small badly-preserved *Goniatites*), and small *Gasteropods*. In the dark slates on the north side of Nail Point by the Tamar there are traces of fossils amongst which *Cardiola* (*Buchiola*) *retrostriata* was recognized. By the Lynher estuary, between Earth and Ince Castle, west of Ince Brake (about 770 yards from Ince Castle) in dark grey slates weathering buff and drab, which in places contain numerous soft brown nodules and nodular bands, of the German *knollen kalk* type, *Bactrites* and small distorted *Goniatites* were recognized. Occasional casts of a small shell resembling *Cardiola*, but with ornaments effaced, were met with in the nodules. East of the above, and south of Ince Castle, *Entomis* and *Styliola* occur in purple and greenish slates.

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[1] *Ibid.*, 1889, vol. xxi., pp. 275, 276.

The traces of *Entomis* are as a rule obscure, and seldom specifically identifiable. Professor Rupert Jones identified *Entomis serratostriata* (Sandb.) and *E. gyrata* (Richter) in specimens of greenish-grey slates obtained at Thancke's Lake, near Torpoint. Similar fossils have been found in purple-red slates by the coast toward Torpoint, and by the road 110 yards west of Thancke's House. *Entomis serratostriata* was also identified by Mr. E. T. Newton, in purple-red slates, in which numerous traces of these cyprids were found some years ago, in a small quarry near the road to Botus Fleming, just north of Carkeel. The slates are here intersected by an intrusive band of sheared diabase. *Entomis serratostriata* and *Styliola* were found in purple, red, and green slates east-south-east and south-south-east of Markwell, between the rivers Tiddy and Lynher.

In the green and purple slates of Antony Park *Entomis* resembling *serratostriata* was obtained; and, in similar slates, by Forder Lake near Antony Passage markings suggestive of *Entomis variostriata* (Clarke) were observed.

Between Markwell and Ince Castle *Entomis* was noted, in tough grey and buff slates by the creek near Wivelscombe Quarry, at 110 yards north-west of the wooden railway bridge (G.W.R.); by the Lynher, near Grove, in purple slates; with *Styliola* in purple and greenish slates near a farm called Dobbins, at about half a mile east of Grove.

Styliola was observed in dark grey slates exposed in the G.W.R. cutting on the west bank of the Lynher, also (with *Posidonomya venusta* (Münst.)) in dark slates in the quarry in Craigs Wood, St. Germans Park, at more than half a mile north of Port Eliot.

In grey slates in Treskelly quarry, on the north border of the St. Germans schalstein near its western termination *Styliolæ* are abundant. *Entomis* and *Styliola* occur in greenish slates in Bake Bottom at about 660 yards to the south of Trerule Fort; also in greenish slates at Tideford near the National School, and in other places near Tideford. At Hay north of Tilland, the farm east of

Trehunist (south-east of Quethiock) not named on the map, markings resembling *Styliola*, and remains of trilobites were noticed in dark grey buff-weathered slates.

On the north of Dannett Wood at Dannett Farm, shown but not named on the map, tough yellowish-brown rock, probably resulting from the decomposition of dark calcareous slates or mudstones, contains numerous traces of small fossils amongst which *Styliola* was recognised.

Specimens collected by Mr. Fox from Roseland quarry contain numerous traces of *Styliola*.

Purple and green slates exposed by the road south of Trenodden at 200 yards from Doddycross contain numerous examples of *Entomis* and *Styliola*.

By the same road south of Trehawke and east of Trehurst (the large farm near Coldrenick, shown but not named on the map) near Padderbury, in grey, purple, and greenish slates *Entomis* and *Styliola* abound. Part of a zaphrentoid coral was also found. South of the above grey slates are exposed in a large quarry by the high road, north of Catchfrench, in which numerous traces of *Styliola* occur.

There is a farm called Trehill, shown but not named on the map, south of Polborder (south of St. Mellion). On the west of this farm, in green slates or mudstones, a small mass of *Entomis* remains was found. The Upper Devonian slates here form an inlier in the Culm Measures and locally exhibit purple colours, as also on the south and west of Vinegar Hill, near Painters Cross. Near Weir Point on the Tamar *Entomis* (probably *serratostriata*) was noticed in purple and green slates.

On the Devon side of the Tamar, numerous obscure traces of *Entomis* have been met with in greenish slates or mudstones by the road from Tamerton Foliott to St. Budeaux, near some cottages called Penwell Cottages on the six-inch map. *Styliola* occurs in grey slates in the vicinity of the grits of Efford in the village of Compton near the border of the adjacent map (349), but no fossils have been discovered in the purple and green or dark grey slates of Devonport Stoke and Mutley. By the Tamerton Creek west of Budshead, dark grey slates with *Styliola* contain bands and lenticles of limestone, the latter frequently decomposed to brown earthy residues. To the north of Tamerton Creek the slates are for the most part pale grey and greenish, rarely if ever reddish.

Near New Park on the Tamar, *Spirifer verneuili* Murch. and markings resembling *Entomis* were found in greenish slaty mudstones.

Spirifers of the same species were seen in grey and greenish slates on either side of the Tavy above Beer Town, and near the boat-house in Blaxton Wood.

Spirifer and *Rhynchonella* were noticed in similar slates in a quarry near the S.W.R. due east of Weir Quay. A lenticle of hard pale-coloured crinoidal limestone, half an inch thick, was observed in the slates to the south of a small mass of intrusive igneous rock in the railway cutting near Furzehill, at about three-quarters of a mile south of Beer Alston Station.

Spirifers were noticed in grey and greenish slates and mudstones by the Tamar near Hole's Hole.

The slates in this part of the district resemble those of Delabole and Tintagel. Although it may be an accidental circumstance, it is curious that *Spirifer verneuili* should occur in similar slates at Delabole and at Holne Bridge, and in similar mudstones at Druid near Ashburton and elsewhere, and rather suggestive of a higher stage in the Upper Devonian than anything within the area of vulcanicity. At Thorn Point and near Hole's Hole, beds of fine-grained greenish grit are intercalated with the slates.

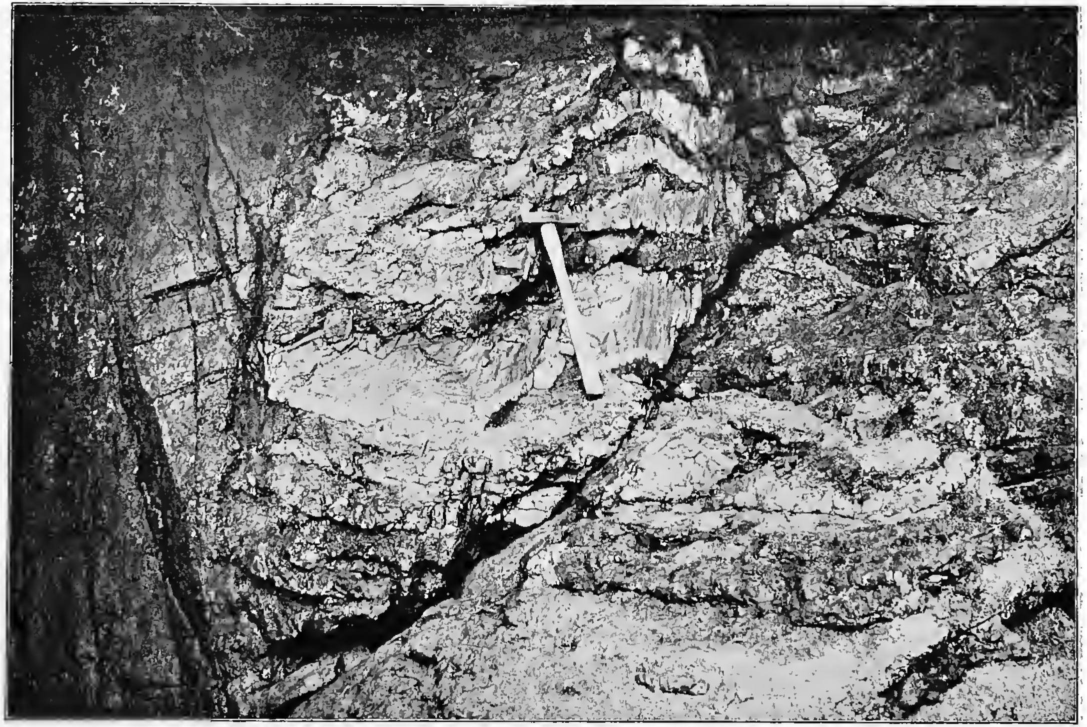
On the north border of the map at a quarter of a mile west of Fursdon (long. 4° 14′ 30″) there is a large disused quarry exposing about 100 feet of dark grey and greenish Upper Devonian slates. The planes dip south at a high angle. The slates seem, from tufa on the quarry face, to be partly calcareous. No fossils were found, but as the search for *Styliolæ* and *Entomis* demands considerable time, this is no proof of their absence. Although the recognisable preservation of these small organisms is exceptional, I have no doubt whatever that with unlimited time at one's disposal the localities in which they occur could be very largely multiplied.

The Wearde-Efford Type.

The absence of volcanic rocks in the districts north of St. Budeaux and Saltash, and their development south and west of these places, in a plicated series of rocks in which the relative distribution of the grey and variegated slates has no very definite stratigraphical value, seems to be explainable only by the localisation of the area of vulcanicity. For, were it otherwise (unless they belonged to an overlying and unconformable group), we should expect to find the volcanic rocks repeated in, or on the north side of, the Botus Fleming and Landulph anticline. This consideration must be taken into account in describing the remarkable occurrences of even-bedded grit, or greywacke, at Wearde and other places in the volcanic districts, and at Compton, Efford, and Crabtree within the western boundary of the adjacent map (Sheet 349). I believe the rocks in the latter district were described as tuffs by Worth in 1886,[1] as he remarks: "Indeed, the Crabtree tuff is at times very deceptively like sandstone." These grits were taken as Middle Culm-rocks, in view of the fact that petrological examination did not warrant their description as tuffs, and owing to their strong resemblance to the Culm Measure grits of St. Mellion and elsewhere.[2] Prior to the petrological examination of specimens from Efford and Wearde by Professor Watts in 1895, I had regarded these greywackes as siliceous tuffs contemporaneous with the Upper Devonian slates and volcanic rocks amongst which they occur.

[1] 'The Rocks of Plymouth,' *Trans. Plymouth Instit.*

[2] *Instit. Mining Engineers*, Sept., 1900, and *Proc. Somerset Archæol. and Nat. Hist. Soc.*, 1900, vol. xlvi.



North of Henn Point. Chert intercalated with vesicular Basalt.

The question as to the age of these rocks is complicated by the occurrence of chert bands interstratified with the vesicular igneous rocks of the coast section in one place between Wearde Quay and Saltash, at about 100 yards north of Henn Point (Plate II.) The interbedded cherts terminate abruptly against igneous rock and, until a recent visit to the section with Dr. Flett, I considered them as part of an overlying interbedded series of Lower Culm chert and lava let down by fault.

The vesicular igneous rocks here and at Devonport Workhouse Quarry (Fig. 15, p. 92)), where chert is also present amongst the in-rolled interstitial sediment, exhibit characteristic pillow structure, and detached pillows with concentric lines of steam cavities are found in the neighbouring slates.

Dr. Flett remarks, after making an examination of microscopic sections of the cherts associated with the pillow lavas: "Several of these cherts show small, pale, rounded spots which have dark centres and are exceedingly like radiolaria, but under the microscope no structure is discernible in these spots which would enable us to say with certainty they are radiolarian. They seem to be clusters of minute grains of dolomite. It is a very critical point, so I took an opportunity of consulting Dr. G. J. Hinde. He agrees with me that the naked eye appearances are exactly those of radiolarian cherts, but the microscopic characters do not confirm this.' There are also three slides of chert from Forder Lake in the Survey collection. None of these show any organisms. It is interesting to observe, however, that they are all true cherts, not baked shales, and that they do not seem to have been formed from the silicification of limestones. The Culm cherts from this Sheet [348] have a quite distinct character from those above mentioned."

These associations of chert with pillow lavas recall those so well described by Messrs. Peach and Horne in the diabase lava of the Arenig rocks near Ballintrae and Downan.[1] Although the occurrence of chert in association with pillow lavas is by no means unusual, in this case it complicates the evidence, as chert with radiolaria ascribed to the Lower Culm has been identified by Messrs. Fox and Hinde in the volcanic rocks at Tavistock, and because fragments of chert in which no organisms could be found occur in rocks of the Wearde greywacke type near St. Erney.

If, therefore, the Wearde greywackes are, as I think, a local phase in the deposition of Upper Devonian sediments in an area of vulcanicity, the chert and associated lavas must also be Upper Devonian; but if the latter were shown by the discovery of Culm radiolaria to be of that age, most, if not all, of the contemporaneous volcanic rocks between Saltash and Liskeard would be Devono-carboniferous, of the same age as the volcanic rocks of Tavistock but not connected with them. In advocating the Upper Devonian age of these grits, the evidence is so finely balanced that I think no apology is necessary for having entertained and published the contrary view. The greywacke beds extend in a connected mass from Wearde Quay westward for half a mile, being well exposed in the railway cutting, in an adjacent quarry, and at Defiance Quay quarry where they overlie diabase. Toward Forder they cannot be persistently traced, but are seen near the proterobase masses on either side of the creek. From here to Trehan they are apparently represented by occasional beds intercalated in the slates.

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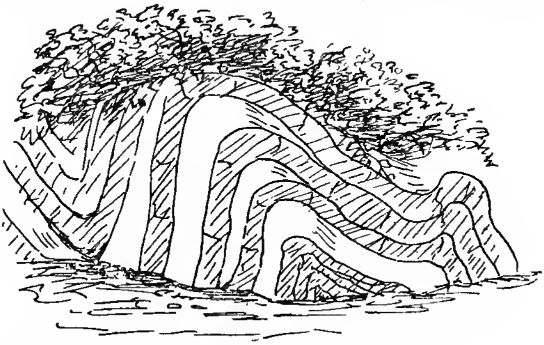
[1] 'The Silurian Rocks of Britain,' vol. i. (*Mem. Geol. Survey*), pp. 40, 431, &c., plates i., ii., iv., v., vi.

At Burraton Combe north of Trematon Castle even beds of rusty-weathered rather fine-grained greywacke are visible at the entrance to a quarry in dolerite, described by J. A. Phillips[1] as—without hornblende, with ilmenite much altered, and with needles of apatite. The relations of the small patch of greywacke to the dolerite are probably faulted. The greywacke beds are next encountered at a mile and a half west of Burraton Coombe, where they form with interbedded dark slates or shales the apparent westerly continuation of a spur of igneous rock to the Lynher bank opposite Poldrissick Quay, not far from the proterobase of Treluggan Wood described by Worth.[2] Between Bagmill and Cumble Tor, a little north of their last mentioned appearance, hard beds of grit and greywacke intercalated with dark slate or shale occur on the east bank of the river, and are also present on the west bank south of Poldrissick, whence they continue, evidenced by surface fragments, on the north of Treluggan to Trewint near St. Erney, where they are apparently thinning out westward through plication or impersistence. In the lane between Trewint and St. Erney, the coarse specimen was obtained with fragments of chert. To return to the Lynher bank, north of Poldrissick, the grits and greywacke beds are visible here and there so intermingled with slates and igneous rocks that it is not possible to treat them as a separate series. By the shore south of Honey's Quarry the interbedded shales

FIG. 11.—*By the Lynher, South of Honey's Quarry.*



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[1] *Quart. Journ. Geol. Soc.*, 1878, vol. xxxiv., p. 491.
[2] 'The Rocks of Plymouth,' *Trans. Plymouth Instit.*, 1886.

and greywacke are beautifully contorted (Fig. 11.), and this indeed is the case wherever they are well exposed in mass. The igneous rocks north of Poldrissick are chiefly vesicular spilites.

J. A. Phillips[1] describes a quarry at Cumble Tor in fine-grained dolerite, in which the felspar is to a large extent unaltered, and augite not abundant, sometimes stained by iron oxide, while the titaniferous magnetite is replaced by the usual light-coloured substance. In the quarry are patches of rock "decomposed into a soft yellowish-grey freestone; sections cut from such specimens are found to consist chiefly of a colourless granular material in which, although shadowy outlines of felspar are sometimes visible, the crystals of that material have generally disappeared. Throughout this are disseminated a few small patches of green hornblende, a little viridite," and some of the grey dust-like material like that resulting from the decomposition of augite. A succession is given in ascending scale of slate, dolerite, slate, vesicular lava, slate. The freestone in the above description is somewhat suggestive of the presence of the greywacke type.

In the same locality south of Cumble Tor Wood a little "fine grey chert without trace of organic structures or of contact effects was found in fine-grained highly vesicular and extremely decomposed basic igneous rock."[2]

From St. Erney westward no further evidence of greywacke is to be found along the direction of their occurrence between Wearde Quay and St. Erney, but the type is again encountered on either side of the River Tiddy at Padderda Wood, about three miles from St. Erney in a north-westerly direction.

On the north margin of Padderda Wood fine-grained hard blue grit or greywacke weathering brown, and in part banded, is exposed. On crossing the stream hard very fine grit seems to be present. The siliceous rocks are associated with dark slates and volcanic rocks. The type cannot be separated from these materials.

Specimens obtained from Padderda Wood are thus described by Dr. Flett: "Fine sheared felspathic grit or greywacke. From the abundance of felspar and particularly of plagioclase in well shaped crystals, there is reason to suspect that this rock contains igneous material. It is not clear, however, whether it was a tuff or a grit with fragments of older igneous rocks. It contains also much chlorite and iron oxide and comparatively little quartz. The felspars are sometimes idiomorphic, and though much broken do not resemble worn derivative materials."

Of another specimen from the same locality, Dr. Flett reports as follows:—"This is a volcanic rock which has been considerably sheared so that its original structure is greatly modified, and there is some doubt whether it was a tuff, a breccia, or a crystalline massive rock. It contains very many plagioclase felspars, often broken, but not uncommonly still so idiomorphic that they are not worn fragments. They lie in a fine streaky sheared groundmass, which may have been the matrix of a porphyritic andesite or basalt, or the finer material between the lapilli in a tuff. It is in many places full of microlithic felspars but varies greatly and irregularly in character, so that it seems most probable that the original rock was not crystalline but fragmental, and the appearance of the hand specimen favours this view. Moreover, here and there a grain of rounded quartz may be detected, and this supports the theory that this is a tuff or breccia. Chlorite and limonite are abundant."

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[1] *Op. cit.*, p. 490.

[2] Note by Dr. Flett.

At half a mile north of Padderda Wood and five-eighths of a mile west of Penpoll, the presence of coarse-grained greywacke, partly conglomeratic, is attested by surface fragments, which seem to be the easterly termination on the summit of a volcanic rock which crosses the road between Tilland and Trehunist in two places north-east of Coombe. Greywacke bands may occur in the slates crossing this road at half a mile south-east of Trehunist; in the grey slates of the vicinity there are banded rocks.

The last indication of the Wearde type is furnished by a few surface stones of greywacke with slate and volcanic stones above Trenant Wood on the west side of the river Tiddy, just above Hepwell Bridge, at a mile and a quarter from Padderda Wood.

The best exposures of the type are at Wearde. In a quarry by the road on the north of the railway over 20 feet of hard rather even-bedded grit and greywacke is exposed, in beds of from 6 inches to 2½ feet in thickness, separated in many places by grey shales with harder ferruginous sandy seams. In the west part of the quarry two or three ovoid patches of softer material are visible; one of these is two feet long and one deep. In another a thin white cherty seam was noticed. In the east part of the quarry the upper beds display a rather coarser grain, and occasionally contain fragments of chert, the rock is here intersected by a small fault. The beds are nearly on their strike in the quarry, but in the cutting on the west side of the bridge over the railway are seen to be extremely contorted. A few yards east of the bridge a fault crosses the cutting throwing the greywacke against an anticline of greywacke upon dark slaty rock with brown interbanding, in nodular looking beds averaging about an inch in thickness (Fig. 12). These slaty beds speedily disappear, and for the remaining hundred yards or so to the termination of the cutting the even-bedded greywackes with occasional dark shaly partings are seen to be sharply bent in a syncline speedily counteracted by an anticline, but between this and their outcrop there is a syncline not shown in the railway which it crosses just beyond the termination of the cutting.

On the west side of the bridge the contortions in the greywacke, probably owing to a nearer coincidence with the strike, are impossible to follow out; dark slaty mudstone is involved, either intercalated in, or just under, the greywacke, in close proximity to an irregular process of intrusive igneous rock probably connected with the diabase in Defiance Quay quarry below. In this mudstone patches of a carious cindery aspect occur; these Dr. Flett, in a visit to the section in 1904, proved to be sections of volcanic bombs. This discovery connects the Wearde greywackes still more closely with the volcanic episode, as they cannot be regarded as a separate series from the mudstone with the bomb bed. At Defiance Quay, through a small enclosed lawn we obtain access to the diabase quarry (Fig. 13). Here the massive diabase[1] (D) overlain by Wearde greywacke and mudstone (Wm) is faulted on the east against greywacke and mudstone containing the bomb bed (*b*). On the west the bomb bed is also visible overlying hard baked rock which is probably separated from the diabase by a concealed fault.

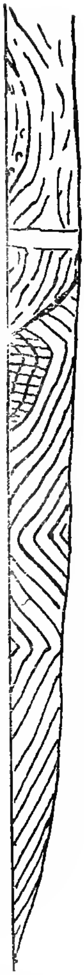

FIG. 12.—*Railway cutting, Wearde Quay.*

The diabase here seems to have been a laccolitic intrusion, from which the irregular igneous rock seen in the cutting above proceeded. A specimen of the diabase sent to Professor Watts was pronounced by him to be 'a decomposed ophitic dolerite now a diabase.'

The line from St. Erney to Wearde Quay prolonged eastward affords no evidence of the presence of rocks of the Wearde type until we reach the eastern border of the map where, on the south margin of the volcanic rock near Emmanuel Church in Mannamead, there is some slight evidence of the presence of ferruginous brown-stained greywacke associated with slate aud volcanic bands, and this horizon followed east across the border of the map into Sheet 349, gave ample evidence of the grits and greywackes in the lane cutting south of Lower Compton village, where they occur in association with dark slates on the south side of the vesicular volcanic rock.

Professor Watts examined specimens of the greywacke from Efford (in Sheet 349) and from the quarry near Wearde Quay. He classed them all as "greywacke grits generally white or pale in colour varying in coarseness and weathering brown." He described one specimen from Efford particularly, the rest being briefly alluded to with reference to it. This specimen (Slide No. 2136), he says, "is made of angular grains of quartz with equal quantities of orthoclase and plagioclase. The quartz grains are often strained as if they had been derived from the denudation of gneisose or schistose rocks. There are also angular fragments of many rocks such as felsite, andesite, and micropegmatite as though the denudation of a volcanic series had also contributed fragments. Magnetite and sphene —the latter included in quartz, are frequent. I have not been able to detect any vesicular lapilli in this specimen or any of the others sliced, so that the term volcanic ash or tuff seems inappropriate to the specimens examined. *Grit* or *volcanic-grit* would be better terms. The rock has been crushed, and pale and brown micas have been developed along the crushing planes." Six specimens not sliced, from the same locality, "look more ashy in hand specimens," one "contains the clay galls so common in ashes," and another "contains ashy material banded with slate." The Wearde specimens were not sliced. Two of these "are nearly quartzites in appearance and do not seem ashy." Three "are more ashy looking." Two "have ashy looking layers banded with slate. Some of the specimens show large fragments of slates." When mapped in 1893 these rocks were noted as tuffs in ignorance of Worth's long previously expressed opinion[1] regarding the greywackes of Compton and Crabtree. Dr. Teall (in 1898) described specimens of the greywacke from Forder Creek and from Wearde quarry. On the east side of the creek there is a large quarry in proterobase. This is the rock referred to under the locality Wearde by J. A. Phillips.[2]

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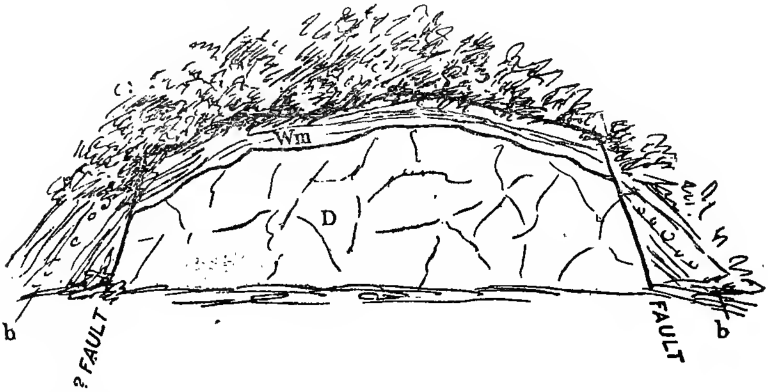
[1] This is not the rock described by J. A. Phillips and by Worth under the locality 'Wearde.'

FIG. 13.—*Diagram of quarry at Defiance Lawn.*



In the same quarry are intensely hard mudstones and decomposed well bedded brown rocks, highly inclined, and apparently contorted with the igneous rock, which is apparently irregularly intrusive. Near the quarry on the south of the proterobase there is a massive brown broken rock of the Wearde type. A little further south an impersistent bluish cherty band half an inch thick occurs in dark slates with occasional arenaceous films. Near this, a chert band was seen in dull green fine-grained volcanic rock which is associated with "an amygdaloidal diabase porphyrite" considered by Dr. Teall to be "a lava from its structure." No organisms were found in the chert.[1] Near this rocks of Wearde type again occur, and on the north the largest mass of vesicular andesite, prolonged westward from the coast south of Saltash, is met with.

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[1] *Trans. Devon. Assoc.*, vol. xix. (1887), pp. 485, 486.
[2] *Op. cit.*, p. 491.

A sliced greywacke specimen from the proterobase quarry is described by Dr. Teall as:—"A greywacke composed of quartz, plagioclase, and apparently fragments of a felsitic igneous rock (abundant). It undoubtedly contains igneous fragments which are either lapilli or portions derived from igneous rocks in the ordinary process of denudation."

A specimen of greywacke from the west bank of the Lynher, north of Poldrissick, is thus described by Dr. Flett: "This rock is apparently an impure, highly felspathic grit. It contains rounded clastic grains of quartz, but felspar preponderates, and is both orthoclase and plagioclase, much weathered. Micas, chlorite, limonite, calcite, and iron ores make up the rest of the rock."

The allusions to, and descriptions of, igneous rocks in the vicinity of the occurrences of greywacke may appear involved and out of place, but they are necessary in order to show the intimate connection that exists in the field between these rocks and the volcanic rocks, which is very much more suggestive of contemporaneous than of long subsequent formation.

It is worthy of remark that the greywackes of Wearde, if prolonged eastward across the Tamar, would be continued in the district between Bull Point and Camelshead Bridge, where, as already mentioned, a sheared igneous breccia occurs. Worth mentions three narrow dykes or bands, perhaps repetitions of the same rock, in this cutting (between the Saltash Road and Westonmill Lake), in which the prevalent colour of the rocks is "ochry-drab or brown." These igneous rocks when examined microscopically "turn out in the main to be ashes rather than tuffs, highly altered, but still retaining shadowy features of their original fragmental structure, with wavy and imperistent brown strings running laterally through them, giving the appearance of fluxion. In parts they enclose small slaty patches, a characteristic of some tuffs at Crabtree, near Plymouth."[2]

He also notices here two varieties which I can match in specimens from the Efford rocks. One of these "may be described as a granular schistose tuff—the distinctly fragmental matters in which are disposed between irregular plates or films of talcose matter, some of which has a greenish hue, and is translucent. Yet another fragmental form is an agglomerate—small bits of rock, some pebbly, some flat, but all with the edges more or less rounded in a friable base."

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[1] Chert was also detected in the dark slates penetrated by intrusive rocks in Antony Passage railway cutting and near Trematon Castle.

[2] *Trans. Devon Assoc.*, vol. xxi. (1889), p. 282.

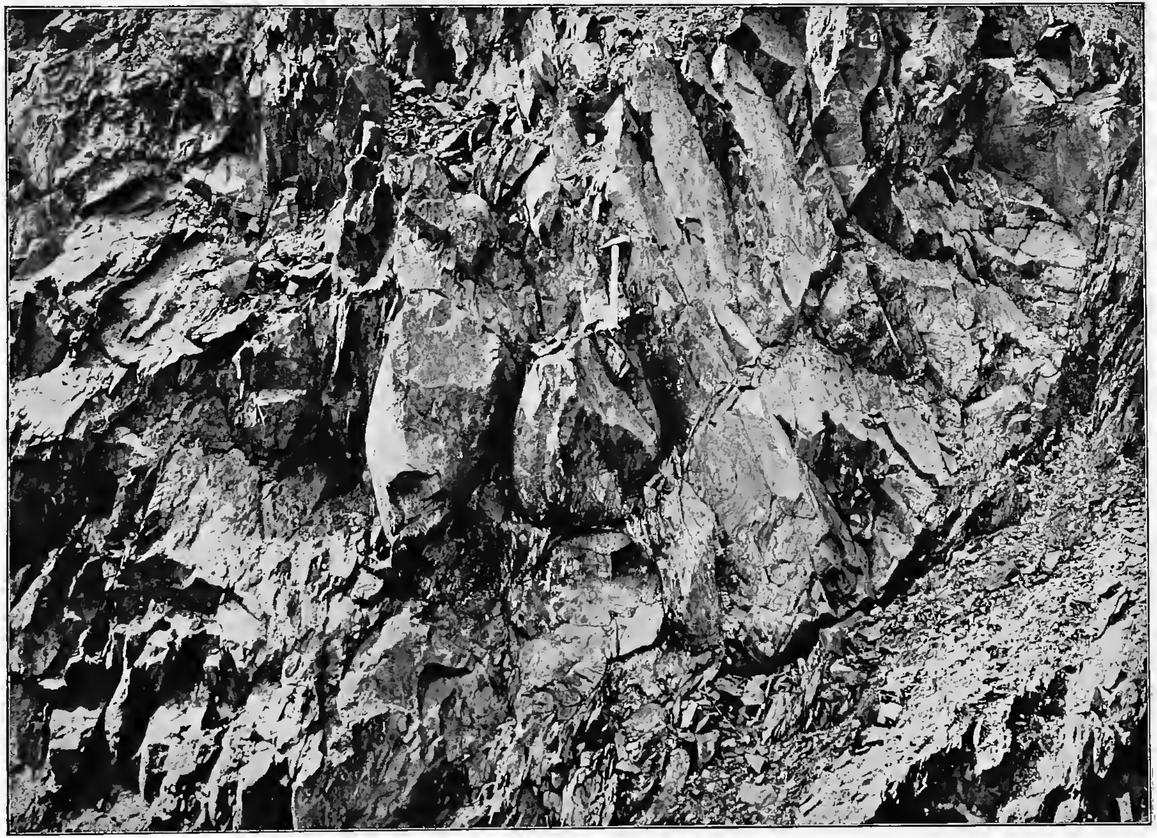
The coarser rock containing chert fragments near St. Erney, and rocks near Lower Compton answer to the description of the last named. The fine-banded intercalations of felspathic-looking materials with dark argillaceous films frequently met with in the Wearde and Efford greywackes are easily explainable on the theory of intermittent showers of fine ash successively silted over. Either as ash or dismembered felstones, varying in coarseness and sifted and arranged in layers by the currents produced by the agitation consequent on small submarine eruptions, the greywacke type may be accounted for more naturally than by assuming their derivation from older rocks by denudation, of which in their arrangement and distribution there does not appear to be one particle of proof. Bands of fine ashy material crossing the cleavage of the dark slates have been noticed on the shores of Westonmill Creek, opposite Nob Quay, but no hard greywacke is to be seen.

Igneous Rocks in the Upper Devonian.

These, whether contemporaneous or intrusive, comprise by far the largest class in the map, and include schalstein tuffs and lavas, andesitic basalts of various types, dolerites, proterobases, picrites, and diabases, as well as numerous examples of rocks which have been so completely changed in character that no clue to their original structure is to be obtained. To the latter class J. A. Phillips calls special attention, citing the intrusive rock in the Carkeel quarries as an example (*Op. cit.* pp. 490, 493). The contemporaneous association of the basalts, breccias, and tuffs is nowhere better shown than in the railway cuttings and on the coast between Wearde Quay and Saltash. The intrusive character of the dolerites is well displayed by the proterobase in Antony Passage railway cutting, in the South Western Railway cutting north of the Albert Bridge and by the adjacent shore of the Tamar.

As regards the indication of the igneous rocks on the map a few remarks are necessary. Where a continuous mass of volcanic rocks occupying a considerable area is shown—as east of Bull Point and between Burraton Coombe, Trehan, Trevollard, and Trematon—it must not for a moment be inferred that these represent the continuous extension of a sheet or sheets of tuff or lava. On the contrary they indicate occurrences of volcanic rocks in the slates in plicated bands or impersistent seams, so badly evidenced on the surface that it is impossible to map them separate or to show them at all without enclosing them by a general line within which in some cases slates very largely predominate.

Several small patches of igneous rock (hard diabase) are shown near Treworgey, north of Liskeard. Some of these are based on the presence of boulders only. Near the northern border of the map where hornstones or rocks approaching that character occur it is impossible to separate those which may be altered igneous rocks, and this is often the case where rocks of this type occur within the granite aureoles elsewhere.



Railway Cutting near Henn Point. Pillow lavas.

The distribution of the volcanic rocks brings out in a marked manner the plicated repetition of the slates in which they occur, and also their localization. They do not represent one continuous emission, but several, perhaps from local vents here and there along their extension, and although it is possible that some patches may be of earlier date than others, there is nothing in their occurrence to render this certain.

Even if the purple and green slates occupy a more definite geological horizon than we are inclined to assign to them, the occurrence of volcanic rocks in them between Notter and Brightor, or elsewhere, is easily explainable by local protraction of eruptions.

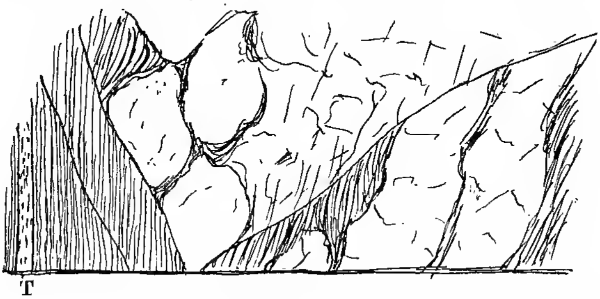
As regards the intrusive greenstones there is every reason to conclude that these are mainly ancient dolerites, as advocated by Phillips, and that they were intruded before the post-Carboniferous movements. The evidences of stress and shear planes in the Clicker Tor picrite as shown in Menheniot Station cutting, and the tendency to a rude contortion displayed in quarries by Forder Creek bear this view out.

It is difficult to dissociate these intrusive masses from the occurrences of volcanic rock in their vicinity, and it seems not unnatural to suppose that, in some cases at least, they were connected with the eruptions as necks or feeders, and the basalts themselves may in places be similarly intrusive.

Intrusive felsites or elvans continuing the line of Roborough Down rock westward enter this map at latitude 50° 28′, and appear here and there at the surface, on the north margin of South Wood, near Lopwell, near Collytown, and crossing the South Western Railway at about three-quarters of a mile south of Beer Alston. These rocks belong to the class of elvans and are, with the probable exception of the Withnoe and Cawsand felsites, the most recent intrusive rocks in the map.

Contemporaneous.—As we proceed from Wearde Quay to Saltash the grey slates soon become associated with igneous rocks, a mass of volcanic breccia being first encountered, then large bombs or small detached pillows of vesicular basalt in the slates; further on, at Henn Point, masses of basalt alternate or are repeated in the slates. At a short distance north of Henn Point thin bands of volcanic rock, displaying a gentle anticlinal structure, were seen to cross the highly inclined cleavage of the slates. Further on we encounter the mass of vesicular basalt with marked fluxion structure, in which the bands of chert already referred to are in one spot intercalated. This mass is separated by slate from vesicular basalt forming the seaward termination of the large mass which extends westward by St. Stephens to the head of Forder Creek. In the railway cutting this mass is split up into three, separated by grey and dull green slates. The junctions are not sufficiently clear to tell whether this is due to repetition by plication or to intercalation. Further north a little igneous rock, which is not seen in the railway cutting, is shown in the coast. On crossing the viaduct traces of igneous rock are again encountered in the slates, by the shore just south of Albert Cottage, Saltash. Here the igneous rock crosses the cleavage of the slates, and displays the character of vesicular bombs or detached pillows, and of tuff with hard grey rock and chert. The rocks of Henn Point are well shown in the railway cutting, in which the pillow structure is very apparent (Plate II., p. 83). Faults or thrusts traverse the section in three places, and a green ashy band a foot thick, with white lapilli and slate fragments (T), occurs in the slates on the left (Fig. 14). The andesitic basalt here exhibits concentric vesicularity.

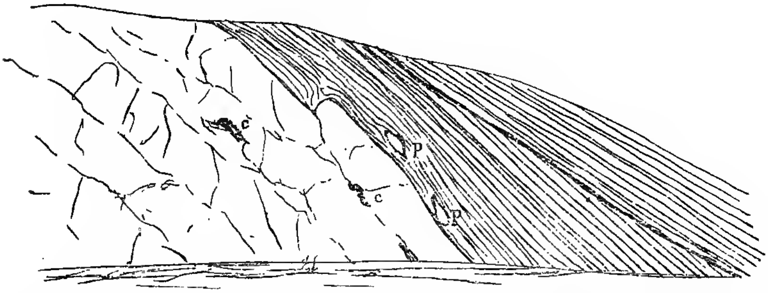
FIG. 14.—*Railway-cutting, Henn Point. Pillow Lava.*



On the shore of Westonmill Creek, at about 100 yards south of Weston Mill, vesicular basalt exhibits an irregularly mammilated or pillow-like junction with the slates which separate it from a smaller mass on the south. The latter is succeeded by grey slates overlain by tuffs, faulted against purple and green slates opposite Nob Quay.

The large mass at Ford and the smaller mass on the north-east of it, near Devonport Workhouse, evidently belong to the same series of tuffs and pillow lavas. The rock in Devonport Workhouse Quarry contains infolded patches of slate, and occasionally of chert (*c c*), and exhibits an irregular pillow-like junction with the overlying slates near the entrance to the quarry. In the lower part of the slates detached pillows of the lava (*p p*) may be detected. The junction on the other side is much more abrupt, conveying the idea of an anticline of the igneous rock.

FIG. 15.—*Devonport Workhouse Quarry.*



Sheared greenish vesicular andesitic basalt occurs in grey slates at Weston Mill, and on the north is a large mass chiefly composed of tuffs with slate fragments and whitish vesicular lapilli, of the same character as the one-foot band in the railway cutting west of Henn Point and the breccia on the coast.

Intrusive.—A small patch of dolerite occurs at Merrymeet which has been described by Phillips[1] under the pseudonym Merrifield. Phillips also describes a proterobase at Pope's Mill, in the Seaton valley, between Liskeard and Menheniot, and a small patch of dolerite intrusive in purple and green slates near Hatt. The well known examples of proterobase at Wearde—a pseudonym for Forder Lake Quarry—and at Grove have been described by Phillips and Dr. Teall; Ernesettle, Treluggan, &c., by Worth. The following specimens of proterobase occur among the Geological Survey slides:—Railway cutting at Antony Passage, and near Passage Point (slides 2,141, 2,142, 2,143), described by Prof. Watts. The following were examined by Dr. Flett:—Grove (slide No. 4,323 on the east bank of the Lynher, slide No. 4,324 on the west bank of the Lynher). North-east of Padderbury in a dyke or sill (slide No. 4,325), Trehunsey Bridge (slide No. 4,328). South-west of Cartuther (slide No. 4,331). North of Cartuther Mill (slides No. 4,332 and 4,333); Pope's Mill is further north. Boulders in wood south of Glenlea (slide No. 4,334).

The picrite of Clicker Tor has been described by Dr. Teall. Boulders between here and Menheniot by Professor Bonney.[2] To these is now added a beautiful example from the vicinity of Criffle Mill, south-west of Molenick, described by Dr. Flett (slide No. 4,329).

Examples of dolerites from Broomhill Grove and Tomboy Hill in Antony Park (slides 2,145, 2,146), and from Looking Glass, near Torpoint (slide No. 2,147) have been examined by Prof. Watts.

Examples of diabase from Burraton Combe Quarry (slide 4,326) and from Poldrissick by the Lynher (4,327) have been examined by Dr. Flett.

The elvans belong to the same class as that of Grenofen in Sheet 338, south of Tavistock—quartz porphyry (slide No. 3,695) described by Dr. Flett—and the Roborough elvans noted by Worth,[3] and have their counterparts in the elvan dykes south of St. Austell, in Sheet 347.

The contemporaneous felsites east of Bull Point have already been described.

Veins of an intrusive, dull-green, dense igneous rock were detected at North Hooe, by the Tamar, on the Devon side, near the north margin of 348 to the west of Whitsom (slide No. 4,337), and also on the opposite bank. These are regarded by Dr. Flett as decomposed lamprophyres (minettes ?) containing corroded quartz xenocrysts, as is frequently the case in Cornish rocks of this group. Specimens were collected by Mr. T. C. Hall from exposures at 100 and 120 yards north of the Ferry on the Devon shore.

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[1] *Op. cit.*, p. 488.

[2] *Journ. Min. Soc.*, vol. viii., 1888, p. 108.

[3] *Trans. Devon. Assoc.*, vol. xix., 1887, pp. 481, 482, 494, 495.

In the South Western Railway cutting just near the northern border of the map a greenish amygdaloidal rock, with siliceous matter in the amygdules, is exposed. Worth regarded it as a lava.[1] It seems to extend for a short distance westward from the cutting, but cannot be traced eastward; if a lava its position is remarkably isolated, unless we assume that it belonged to a series elsewhere removed by denudation prior to the deposition of the Culm greywacke, of which there is an outlier near it in the adjacent map 337 on the north. Due west of this, in the valley west of Fursdon, decomposed igneous rock occurs near the Culm and Devonian boundary. Further south, in the railway cutting east of Whitsom, a decomposed igneous rock with a tendency to spheroidal structure is seen to be irregularly intrusive in the Upper Devonian slates. This is probably the lamprophyre mentioned by Worth.[2]

PETROGRAPHY OF THE IGNEOUS ROCKS.

BY DR. J. S. FLETT.

The Upper Devonian volcanic rocks (lavas) of this sheet have a close similarity to those already described from the Middle Devonian, but are more varied, and in some cases better preserved. They are all, however, a good deal decomposed, and, while their felspars are often fresh and clear, their ferromagnesian minerals are represented only by secondary products, especially chlorite. These rocks are very frequently vesicular, containing numerous amygdules of calcite, which appear as white spots in a green or greyish-green matrix (Fig. 3, Pl. 4). Most of them show no phenocrysts in the hand specimens, though a few are visibly porphyritic with large crystals of idiomorphic felspar. Nearly all are sheared, though in different degrees; the more vesicular have their steam cavities flattened into thin lenticles, and attain a schistose character; the more massive show the effects of deformation better under the microscope than to the naked eye. Only a very few specimens in the collection are in a purely massive condition.

Schalsteins.—Many of these rocks in their sheared state, their abundant calcite and chlorite, and their satiny lustre on the cleavage surfaces, correspond in all respects to the schalsteins of German petrographers. Some of them are undoubted tuffs (Fig. 2, Pl. 4), with original fragmental structure quite evident; but the more vesicular lavas, under the pressures to which they have been subjected may break up into fine breccias, which are very hard to separate from true pyroclastic rocks. The distinction is often of no great importance, as in any case they were a contemporaneous interbedded series. In some of these finer schalsteins the decomposition is very advanced, and all that can be made out in the microscopic sections is that flattened lenticles of calcite lie scattered through a matrix of chlorite, secondary quartz, iron oxides, and residual felspar. This matrix may be highly sheared, approaching to a calc-chlorite schist or may still retain indications of having once been a fine-grained igneous rock.

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[1] *Trans. Devon. Assoc.*, vol. xxi., 1889, p. 275.
[2] *Ibid.*, vol., xxi., 1889, p. 275.

Spilite.—The majority of the specimens, however, are in better preservation than this, and may be described as corresponding exactly to the *diabas-mandelstein* and spilite group of basic lavas, as defined by Zirkel and by Rosenbusch. They are fine grained, usually very vesicular rocks, without conspicuous phenocrysts. The microscope shows that their only fresh original mineral is plagioclase felspar. It takes the form of long narrow prisms, which are often irregular, and may be pointed at their terminations, but very frequently yield sharply rectangular sections which may be ten times as long as broad and contain small devitrified enclosures. These little felspars have often a most perfect fluidal arrangement, forming winding streams in a dark groundmass, and curving round the globular steam cavities. They are usually simply or repeatedly twinned, and from their low angles of symmetrical extinction and low refractive index obviously consist of oligoclase and albite-oligoclase.

No olivine is present in any of these rocks, and the microscopic appearances are opposed to the belief that this mineral was formerly present. They must, however, have contained augite, though now it is entirely decomposed. It cannot have formed large idiomorphic crystals but only small grains in the groundmass. Chlorite, quartz, and calcite represent it. The groundmass also is filled with these minerals, but must have been in some measure vitreous, at least in the finer-grained rocks. Crystals of ilmenite weathering to leucoxene are common, but apatite is not frequently seen in the slides.

Many of the specimens contain small phenocrysts of plagioclase felspar, not differing in composition apparently from those of the groundmass, but yielding good rectangular sections while the latter are frequently acicular, or microlithic. These felspars contain many squarish enclosures, formerly glassy, but now entirely devitrified and decomposed. Where the rocks have been crushed their sections are often broken, the severed parts being slightly displaced relatively to one another, but still showing that they were originally continuous. A single elongated crystal may break into six or more segments arranged along a curving line. Beyond this the shearing has not frequently gone, and evidently the matrix has been more plastic than the larger crystals and has suffered to a greater extent than these.

These fine vesicular spilites are the prevalent Devonian lavas of the Plymouth area. A few examples of them may be cited. Around Henn Point and in the railway cutting west of Saltash all the lavas seem to be of this type, and very similar rocks occur at Brightor (Landrake), at St. Budeaux Church, at Venton Wood (near Tideford), and at Weston Mill. Other localities for these rocks are at the Hartley reservoir, near the Raglan Barracks, at Cumble Tor Wood, and at Poldrissick. In some of these rocks the small rectangular sections of the phenocrysts are more conspicuous in the slides than the decomposed remains of the groundmass. An example of this type is to be found at Lollaberry Quarry, near Saltash.

A limited number of the rocks of this group carry large porphyritic felspars, a feature unusual in the spilites. The best and most accessible instance is the rock quarried behind Devonport Workhouse (Fig. 1, Pl. 4). It is pale greyish green, not evidently vesicular or much sheared in the hand specimen, and shows porphyritic felspars often half an inch in length. Microscopic slides prove this rock to contain a matrix essentially similar to the fine-grained spilites of this district. It consists of acicular felspars lying in a matrix of chlorite and devitrified glass. Calcite is abundant, and with chlorite fills large elliptical steam cavities. Fluxion structure appears in the groundmass, and is accentuated by a slight amount of shearing which has flattened the vesicles, and in a few cases has shattered the porphyritic felspars. The large felspars are idiomorphic, show Carlsbad, albite and pericline twinning, and have the optical properties of albite-oligoclase and a refractive index equal to or lower than that of the Canada balsam in which the slide is mounted. They contain enclosed patches and veins of chlorite and calcite. The specific gravity of small fragments of this felspar proved to be 2.63, thus confirming that a plagioclase very near albite was present.

On account of the unusual character of this rock, which though evidently resembling in many ways the augite andesites and andesitic basalts, contained felspars very rich in soda, a chemical analysis of it was made by Dr. Pollard in the Survey's laboratory. It is given below, along with other analyses of allied rocks cited for comparison. It may be mentioned that large idiomorphic felspars occur also in a few other spilites of this sheet, in several localities along the railway and shore south of Saltash, and at Penquite Quarry.

The large percentage of carbonic acid in our rock shows that it is considerably decomposed, an inference confirmed by the presence of 4 per cent. of water. The carbonates are principally calcite, but some dolomite and siderite are present also, as can be proved by attacking the powdered rock with weak acid. The very low silica and high alumina are also noteworthy. Analysis II. is of a rock from the Southern Uplands of Scotland, described by Dr. Teall.[1] He notes that the special features of his analysis are the high percentage of alkalies combined with a low percentage of silica; the felspars of this rock are oligoclase. Analysis III. is of a spheroidal 'basalt' from Point Bonita, California, cited by Dr. Teall; it shows the same features. Analyses IV. and V. are by Phillips,[2] of Devonian igneous rocks from Pentire Point and Port Isaac, Cornwall. They show that this type of rock has a wide distribution in the south-west of England.

It is curious to remark that the first two of these rocks have a marked pillow-structure in the field. This peculiar feature is exhibited by some at least of the Upper Devonian lavas of the Plymouth area, as was observed by Mr. Ussher and the writer at the cuttings in progress south of Saltash. Moreover, the Scottish rocks and the California rock are accompanied by cherts, and at Henn Point, near Saltash, and in Devonport Workhouse Quarry grey cherts rest on the Devonian lavas or are involved in their mass, perhaps by shearing. The pillow lavas of Mullion Island belong also to this group, and radiolarian cherts accompany them.

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[1] Memoirs of the Geological Survey: 'The Silurian Rocks of Britain,' vol. i., p. 85.

[2] Phillips, J. A. 'On the so-called "Greenstones" of Central and Eastern Cornwall,' *Quart. Jour. Geol. Soc.*, vol. xxxiv., 1878, p. 482.

Analyses of Devonian Volcanic Rocks.

—	I.	II.	III.	IV.	V.
SiO_2	40·55	46·4	49·55	43·23	40·05
TiO_2	2·95	·24	2·23	...	...
Al_2O_3	16·65	20·4	17·58	21·37	20·46
Fe_2O_3	1·13	6·9	3·41	1·69	1·83
FeO	9·46		3·41	9·53	12·66
MnO	·20	...	...	trace	trace
(CoNi) O ...	·07	...	...	...	...
CaO	6·06	7·7	7·20	6·66	6·62
MgO	5·20	3·5	4·05	3·57	4·28
BaO	nt. fd.	...	...	...	...
SrO	nt. fd.	...	...	...	...
Li_2O	? trace	...	...	...	...
K_2O	·27	·54	1·57	trace	trace
Na_2O	4·76	6·93	5·83	5·63	4·82
H_2O (above 105°C)	3·89	1·1	...	3·98	4·30
H_2O (at 105°C)...	·27		...	·51	·56
P_2O_5	·73	...	Loss on ignition 4·34	·97	·63
CO_2	7·85	5·8	...	2·61	3·67
S	·10	...	...	FeS_2 ·33	trace
Cl	nt. fd.	...	...	...	...
	100·14	99·51	99·07	100·08	99·88

I. Porphyritic spilite, Devonport Workhouse Quarry (Anal. W. Pollard).
II. Amygdaloidal diabase, Gatelochside Burn, New Camnock.
III. Spheroidal basalt, Point Bonita, California.
IV.[1] Amygdaloidal lava, Pentire Point, Cornwall.
V.[1] „ „ Port Isaac, Cornwall.

The intrusive igneous rocks among the Upper Devonian strata of this sheet are diabases, proterobases, and picrites. Many of them have been described by Phillips,[2] while others have been investigated by Allport,[3] Worth,[4] and Dr. Teall.[5]

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[1] Phillips, J. A. *Ibid.*, p. 482.
[2] *Ibid.*, p. 471.
[3] Allport, S. 'On the Metamorphic Rocks surrounding the Land's End mass of Granite.' *Ibid.*, vol. xxxii., 1877, p. 422.
[4] Worth, R. N. 'The Igneous and Altered Rocks of South-West Devon,' *Trans. Devon. Assoc.*, vol. xix., 1887, p. 467.
[5] Teall, J. J. Harris. 'British Petrography,' 1888.

In the hand specimens they are coarser-grained than the lavas, never vesicular nor distinctly porphyritic. Their structure is usually a variety of that described as ophitic, and while some of them are very fresh, the majority are a good deal decomposed. As contrasted with the lavas they yield little calcite on weathering, while epidote is a frequent product. Apparently because of their more massive character they are less sheared than the schalsteins and spilites, but symptoms of cataclastic action are very common also in this group.

Diabases.—The diabases are on the whole more numerous than the proterobases. They consist of plagioclase felspar and augite and have a very pronounced ophitic structure. Large plates of pale brown or purplish brown augite may be seen in the sections enveloping many small lath-shaped sections of felspar. Sections of this augite cut nearly perpendicular to an optic axis have peculiar dark blue and brownish grey polarisation tints, and a marked dispersion. The augite is often very fresh, but in other cases is weathered to aggregates of pleochroic green chlorite. Uralitisation, so common in the greenstones of Western Cornwall is very rare in these rocks. Calcite also is comparatively uncommon, but epidote occurs frequently in small bright yellow grains. The iron oxide is ilmenite or titaniferous magnetite, and is often replaced by networks of sphene or leucoxene. Biotite is found in the diabases of Poldrissick and Pillaton Mill. Apatite in large elongated hexagonal prisms is universal. No fresh olivine was seen in any of the slides, but pseudomorphs which may represent that mineral occur in rocks of this group from Burraton Coombe and Cremyll Passage, Mount Edgcumbe. It is probable, however, that most of them were olivine-free diabases. Some of the specimens from Burraton Combe contain large porphyritic plagioclase felspars.

Many of these rocks are much decomposed, and hence do not invite minute description. One point, however, which deserves notice is the presence of alkali felspars in irregular plates as the last product of consolidation. The prevailing felspar is oligoclase, but in a few of these diabases, like that which occurs half a mile north of the east end of the Victoria and Albert Bridge there are plates of untwinned alkali felspar forming a sort of embedding material in which the lath-shaped plagioclases lie.

Proterobases.—The proterobases are distinguished from the diabases by containing brown primary hornblende. As these rocks are always very little sheared there is no reason to regard this mineral as of dynamometamorphic origin, in fact it bears all the characters of an original ingredient. In this group we shall include the hornblende dolerites or hornblende diabases described by Dr. Teall.[1] As dark brown biotite is very common in some of these rocks the term mica diabase is applicable also. They are usually more coarsely crystalline than the augite diabases above described, though fine-grained varieties occur. Ophitic structure does not characterise the majority of them; in fact they tend to have a hypidiomorphic granular texture.

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[1] Teall, J. J. H. 'British Petrography,' 1888, p. 233.

On both sides of the River Lynher, near Grove, and on the west bank of the stream a few hundred yards higher up there are exposures of intrusive rocks of this class. There is a good deal of variation in minor characters even in specimens taken from a single locality, and none of them is in a perfectly fresh state. All contain a purplish augite not unlike that of the diabases but more deeply coloured. It is often surrounded by or intergrown with dark brown, highly dichroic hornblende. The latter mineral does not readily decompose, while the augite is frequently partly replaced by chlorite. Ilmenite in large crystals is abundant, and the long stout needles of apatite which are plentiful in this rock are very conspicuous in the micro-sections. Biotite is scarce. The felspars are not always fresh enough to be determinable, but belong partly to oligoclase, and a small amount of untwinned felspar with low refractive index can be detected in interspaces. There are patches of albite with epidote and calcite which are probably secondary.

The structure of this rock is partly ophitic as the large augites and hornblendes are often penetrated by small felspars, especially near their margins, but they show this character in a far less marked fashion than the diabases, and there is an evident tendency for the felspars to crystallise after the ferromagnesians. An analysis of one of these rocks from the quarry opposite Grove is given below (I.).

In Forder Creek there is a quarry in proterobase, and several other outcrops occur here also on both sides of the stream. This rock has the same purplish augite, abundant ilmenite and large apatites as those above alluded to, but here biotite rather than hornblende is the characteristic mineral. As remarked by Phillips[1] this rock varies greatly, some specimens being coarse and felspathic while others are dark and fine-grained. The ophitic structure, which is very pronounced in some of the slides, is almost absent in others. The augite, biotite and hornblende all may be penetrated by felspar or may show fairly good outlines and be nearly free from enclosed felspars. Epidote, albite, quartz, sericite, calcite, leucoxene and chlorite are the principal secondary products. The rock from the quarry was analysed by Phillips and his analysis is quoted here (IIA and IIB). Among the plagioclase felspars oligoclase appears to preponderate, and there is a certain amount of anidiomorphic interstitial untwinned felspar which belongs to albite and anorthoclase.

Near Cartuther (Roseland), Menheniot, there are two exposures of proterobase which in some respects differ from those described. They are coarse grained rocks, very rich in crystals of dark brown hornblende and containing almost no pyroxene (Fig. 5, Pl. 4). Biotite appears in some of the slides but is not exactly common. The felspar is very fresh and is mainly oligoclase in elongated, nearly idiomorphic crystals, with some alkali felspar, mostly untwinned, filling up the spaces between the earlier minerals. Large prisms of apatite are very common and there are the usual crystals of ilmenite. Chlorite and epidote are the principal secondary products. The structure is not at all ophitic but the hornblende forms well-shaped crystals which are not penetrated by felspar. The amount of alkali felspar is exceptionally large. The results of an analysis of this rock by Dr. W. Pollard are given below (III.). In several respects this rock resembles the Essexites.

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[1] *Loc. cit.*, p. 491 Phillips gives the locality as Wearde, but Mr. Ussher informs me that Forder Creek Quarry is the source from which his specimens were obtained.

In Antony Park and at Antony Passage there are several outcrops of intrusive rocks, as indicated on the map. All of these are hornblende diabases or proterobases, not unlike the rocks from Forder Creek on the opposite side of Lynher. They are a good deal decomposed and their augite is full of chlorite while their felspars are often turbid and semi-opaque. At Defiance Lawn, Wearde Quay, there is a quarry yielding mica diabase, very rich in dark biotite but with little hornblende. Mica diabase occurs also on the east side of Saltash Passage a little north of the Victoria and Albert Bridge. Fine-grained proterobases, more like those of Cartuther and very rich in dark hornblende but containing less augite or biotite, are represented in the collection from Ladye Park (Liskeard), waterfall N.W. of Shillingham, and Trehunsey Bridge. All the members of this group are marked by abundant apatite and ilmenite and a considerable amount of alkali felspar.

—	I.	IIA.	IIB.	III.
SiO_2	42·88	46·42	46·37	47·19
TiO_2	3·68	...	...	2·09
Al_2O_3	14·31	20·23	20·42	13·96
Fe_2O_3	4·70	4·43	4·45	3·39
FeO	9·14	5·89	6·02	9·01
MnO	·32	trace	trace	·47
$(CoNi)O$	0·07	...	...	·04
CaO	10·90	5·99	6·08	8·08
MgO	5·67	3·82	3·87	7·10
BaO	nt. fd.	...	...	·06
SrO	nt. fd.	...	...	...
Li_2O	trace	trace	trace	trace
K_2O	1·92	1·95	1·83	·70
Na_2O	2·52	5·00	5·09	4·50
H_2O (above 105° C)	2·52	2·02	2·00	2·56
H_2O (at 105° C) ...	·25	·32	·30	·12
P_2O_5	·54	·98	·85	·56
CO_2	·13	2·32	2·31	·79
S	·22	...	...	FeS_2 ·11
—	100·07	99·37	99·59	100·73

I. Proterobase from quarry on west side of Lynher opposite Grove Landrake, Cornwall (Anal. Dr. W. Pollard).

IIA. and IIB. Analysis in duplicate of proterobase from quarry on east side of Forder Creek, Cornwall. (*Quart. Journ. Geol. Soc.*, vol. xxxiv., p. 492.)

III. Proterobase, 200 yards north of viaduct, south-west of Cartuther, Cornwall (Anal. Dr. W. Pollard).

Picrites.—The picrite of Clicker Tor, Menheniot, which occurs within the borders of this sheet has been excellently figured in Dr. Teall's 'British Petrography' (Pl. II., Fig. 2), and is well known to all students of the subject. A new locality for hornblende picrite has been discovered by Mr. Ussher at Molenick, Criffle Mill (Fig. 4, Pl. 4). It is a fairly coarse-grained, very dark green rock, and in the hand specimen, the large cleavage surfaces of black hornblende show characteristic 'lustre-mottling' from the numerous small rounded enclosed olivines. Under the microscope the latter mineral is still in large measure fresh, but is weathering to green and yellow serpentine. Brown hornblende is next in abundance. Its crystals are large but entirely without crystalline outlines and show an intense pleochroism. Occasionally small areas of purplish brown augite are visible in the centre of masses of hornblende. Brown biotite, partly bleached by decomposition, and perhaps not entirely primary, occurs here and there in the slides. There are also saussuritised residues of felspar and many large prominent apatite needles. Primary iron ores are few and small, but where the olivine is decomposing dusty iron oxides are separating along its cracks. The poikilitic structure, so characteristic of this group of rocks, is exceedingly well marked, and symptoms of crushing are almost absent.

The results of an analysis of this rock, executed in the Survey's laboratory, by Mr. E. G. Radley, are as follows:—

SiO_2	39·14
TiO_2	1·66
Al_2O_3	7·59
Fe_2O_3	5·26
FeO	8·76
MnO	·56
$(CoNi)O$	·11
CaO	5·91
MgO	22·78
K_2O	1·09
Na_2O	·60
H_2O (at 105° C.)	·56
H_2O (above 105° C.)	6·30
P_2O_5	·38
BaO	nt. fd.
Li_2O	tr.
	100·70

PLATE IV.

PHOTOMICROGRAPHS OF ROCK SECTIONS.

FIG. 1.—*Porphyritic Spilite*; **Quarry near Devonport Workhouse. Slide No. 2148. Magnified 13 diameters.**

The photograph shows large phenocrysts of oligoclase-albite, in a groundmass containing smaller felspars but much decomposed. This rock contains small vesicles occupied by calcite and chlorite. There are no fresh ferromagnesian minerals.

FIG. 2.—*Schalstein Tuff*; **Sewer under George Street, Plymouth. Slide No. 4309. Magnified 10 diameters.**

The rock consists of highly vesicular, decomposed lapilli.

FIG. 3.—*Schalstein*; **high road near Hartley reservoir, north of Plymouth. Slide No. 4306. Magnified 10 diameters.**

The rock shows microporphyritic, elongated felspars, in a fine, dark, decomposed matrix. There are many steam cavities, filled with calcite, flattened and distorted by pressure.

FIG. 4.—*Hornblende Picrite*; **near Criffle Mill, south-west of Molenick, Menheniot. Slide No. 4329. Magnified 10 diameters.**

Many partly decomposed crystals of olivine lie in large masses of deep brown hornblende (lustre mottled structure). There is also a little brown augite and secondary products after felspar.

FIG. 5.—*Proterobase*; **crag overlooking valley, 200 yards north of viaduct, south-west of Cartuther, Menheniot. Slide No .4770, Magnified 9 diameters.**

This rock contains many large eumorphic crystals of dark-brown hornblende, purplish augite (partly chloritized), and transparent felspar, with iron oxides and apatite. The black spots in the photograph are mostly sections of hornblende.

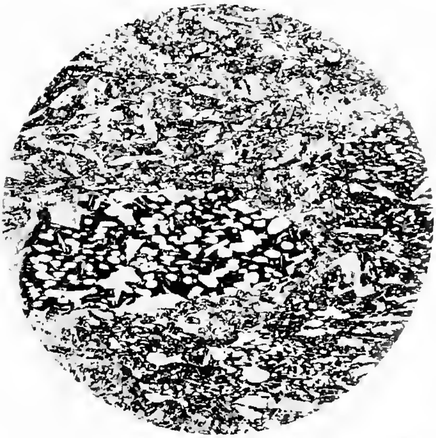

Fig. 2.

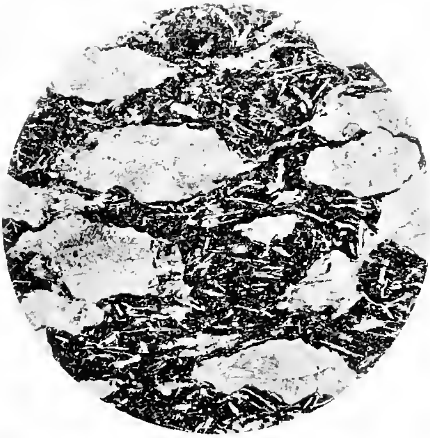

Fig. 3.

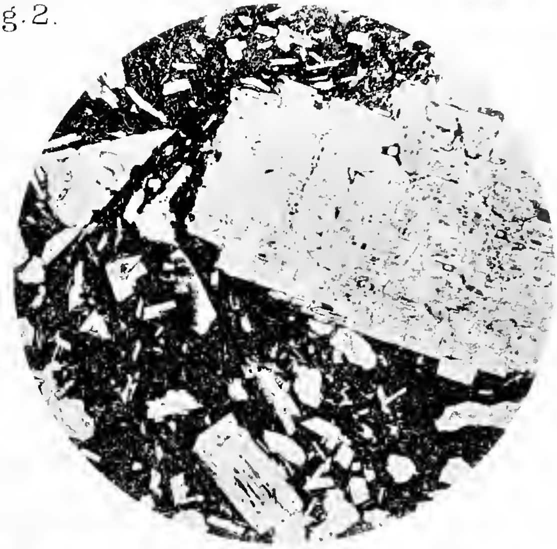

Fig. 1.

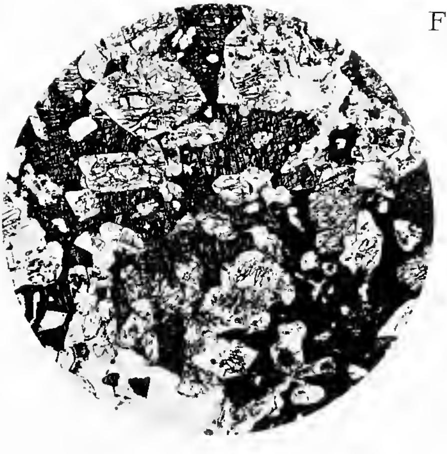

Fig. 4.

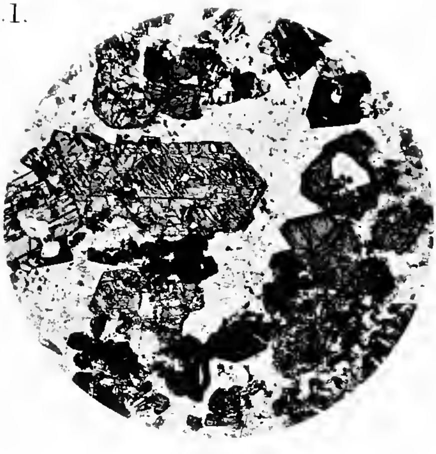

Fig. 5.

IGNEOUS ROCKS OF PLYMOUTH DISTRICT

CHAPTER V.

CARBONIFEROUS.

Extent and Relations.

The Culm Measures extend along the north margin of Sheet 348 for six miles from Haymarsh on the east to Dunnerdake on the west, occupying an area of about seven square miles.

They form an outlier of which about four square miles is comprised in Sheet 337 on the north. Their southern boundary from Pillaton westward is a fault or series of faults, and there are also numerous faults affecting their relations to inliers of Upper Devonian slates, for instance along the valley north of Crendle Down, near Painters Cross, between St. Mellion and Haltonquay, near Heathfield, Haymarsh, and east of Amytree.

These faults, however, do not explain the relations of the Culm Measures to the Upper Devonian or the abnormal distribution of the Lower Culm Measures. The development of Lower Culm Measures at Crendle Down, Newton Ferrers, Herod Down, and Pillaton, their presence at Rouse, Polborder, near Painters Cross, north of Painters Cross, near Haltonquay, and as an inlier on Amy Down renders the direct superposition of the (Middle Culm) plant-bearing slates and greywacke on the Upper Devonian slates between Rouse and Painters Cross, east of Amytree, east of St. Mellion, near Fursdon, and in the outlier at Pentillie Castle an enigma.

Two alternative explanations of these anomalies naturally present themselves:—1st, Thrust faults, often horizontal, displaced by normal faults; 2nd, A marked unconformity between the plant-bearing shales and greywacke and the Lower Culm, allowing of the complete removal of the latter by a denudation so irregular that a considerable representation of Lower Culm was locally left.

Without denying the possibility of the former view, I have adopted the latter, as being in accord with the time which must almost necessarily have elapsed between the deposition of the fine Lower Culm rocks and the accumulation of the comparatively coarse greywacke associated with the plant-bearing shales; and as it is consistent with the occurrence of different horizons of the Lower Culm in junction with the Middle Culm greywackes.[1]

LOWER CULM MEASURES.

The occurrence of Lower Culm at and south of Dunnerdake is extremely doubtful owing to the absence of exposures. At Upham, the farm shown on the map north-west of Dunnerdake, dark shales were seen, but a very thin band of grit was detected in them; a little to the west greenish Upper Devonian slates are visible. The faulted junction can be traced, but whether the tract shown on the map as Lower Culm belongs to that series or to the greywacke is quite uncertain.

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[1] *Proc. Somerset Arch. and Nat. Hist. Soc.*, vol. xlvi., 1900.

On Crendle Down the evidence of occasional surface stones on a barren furze-grown waste suggests dark shales with chert on dark shales or slates resting on greenish Upper Devonian, but, although these dark beds (apparently dipping south) are exposed on the north-west of the Down, their relation to the Devonian on the west is exceedingly obscure. Some evidence of a small greywacke outlier was noted on the Down.

The shale and chert beds of Crendle Down and the strip of Upper Devonian on their north border are cut off against greywackes by fault on the north-east. Toward Herod Down they pass under the greywacke series, partly concealed by a river terrace. Where the greywacke series on Herod Down approaches the faulted Upper Devonian boundary hard grey buff-weathered fragments of shaly stone exhibit numerous impressions of *Posidonomya* and of *Glyphioceras spirale* (Phil.), which characterize the Upper horizons of the Lower Culm at Waddon Barton, near Trusham, and elsewhere. The type here presented is the Brimley type.[1]

On the east of the Lynher valley at, and north of, Newton Ferrers the Lower Culm, as far as could be ascertained, consists of—hard blue-black chert and mudstone beds exposed in a quarry in Park Wood—hard dark mudstones weathering pale green, seen between Park Wood and Newton Ferrers—hard grey mudstones with whitish and black bed banding exposed in a quarry by the avenue near Newton Ferrers; but no proof of the occurrence of the higher fossiliferous horizons was obtained. Continuing their main outcrop we lose traces of the higher horizons in the Lower Culm between Herod Down and Pillaton. On the east of Herod Down an *arrête* of hard dark contorted chert and cherty beds is conspicuous. The beds attain to two inches in thickness. On crossing the Lynher, by a road bordering the alluvium (at the foot of Tor Down), chert beds and dark slaty rocks with cherty bands are exposed dipping northward, and vertical a little further to the north. Between the tributary streams below Trewashford hard blue-black even-bedded cherty beds, varying from half an inch to two inches in thickness, are exposed in a small quarry. At about 80 yards south of this (in Butternhill Wood) similar rocks and shales partly banded with lighter tints were seen in a small quarry.

A quarry by the road near their faulted junction with the Upper Devonian, at three-eighths of a mile west of Pillaton Church, exhibits blue-black chert in beds from one to six inches thick, with shale partings in places, so excessively contorted that their thickness may be under 15 feet. From here to Pillaton Church the outcrop of the Lower Culm is very narrow. At a quarter of a mile east of the church the contorted chert beds are again visible in quarries on a ridge feature, bounded on the south and east by the greywacke series. The chert was here found by Mr. Fox to be filled with radiolarian casts, 20 feet of light and dark banded chert in beds of from one to nine inches thick being noticed in a quarry 500 yards east of the church.[1] On the north of this ridge the relations of the Lower Culm to the greywacke series are not clear. The siliceous beds of the Lower Culm are exposed south-east of Rouse on the west side of the stream, east of which the greywacke series separates the Devonian inliers. At a quarter of a mile north of Rouse siliceous surface fragments denote an inlier of Lower Culm, terminating in a feature on the west. When traced eastward across the valley (at Trehill Wood) the greywacke on its southern border disappears, and for about 300 yards it is in contact with the Upper Devonian; here they are exposed in a quarry with southerly dip, beyond which there is no further proof of their continuance eastward.

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[1] 'The British Culm Measures,' *Proc. Som. Arch. and Nat. Hist. Soc.*, **1892, vol. xxxviii., p. 131.**

To return to the southern margin of the outlier. After the termination of the chert beds on the ridge east of Pillaton nothing but the greywacke series bounded on either side by Upper Devonian is evidenced for a quarter of a mile eastward, then, on traversing two stream valleys, we find dark chert beds with filamentous quartz veins sharply contorted, and not far from their exposure plant-bearing shales and greywacke were seen on the north. From here to Vinegar Hill, south of Painter's Cross, sometimes the one series sometimes the other prevails, and boundaries between them are nowhere clear. At Vinegar Hill micaceous greywackes, associated with pale grey-weathered shales, are faulted on the south against buff and purple Upper Devonian slates, but on the north and east dark slates or shales and chert beds are evidenced in faulted junction with the Upper Devonian; their eastern termination is a small fault-bounded patch. Radiolarian chert was noticed in the foundation of some cottages on the east side of Vinegar Hill by Mr. Fox.[2] North of Painter's Cross another patch of Lower Culm is feebly evidenced; it seems to be in faulted contact with Upper Devonian on the east, but on the north-west and south its relation to the greywacke series is absolutely undefined. Near the apparent westerly termination of this patch, at about 600 yards north-west of [Painter's] Cross, Mr. Fox notes the occurrence in a roadside gutter of hard dark chert "traversed in all directions by veins of quartz. The rock is filled with radiolaria, some even showing traces of structure."[3]

The Lower Culm near Rouse, and between Painter's Cross and the Pillaton ridge, is not distinguished by colour on the map through an oversight.

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[1] "The Radiolarian Cherts of Cornwall," *Trans. Roy. Geol. Soc. Corn.*, 1896, vol. xii. pp. 61, 62; also *Trans. Devon. Assoc.*, 1896, vol. xxviii., p. 787.

[2] *Quart. Journ. Geo. Soc.*, vol. li., 1895, pp. 624, 625.

[3] *Ibid.*

Lower Culm Measures are exposed on the shore of the Tamar, at about 200 to 620 yards above Haltonquay. In this distance the higher horizons of the Lower Culm are visible as well as the chert beds, but the exposures are not continuous and the rocks are greatly disturbed. The greywacke series also comes down to the shore in places and apparently overlies the whole section unconformably, as the Lower Culm cannot be traced inland.

At 330 yards from Haltonquay in the shales and lenticular limestones there is a mass of brownish mudstone with a slaty tendency. This rock is crowded with *Posidonomya becheri* (Bronn). At about 60 yards further north hard dark chert beds with filmy quartz veins are exposed in a cliff receding from the shore. At 60 yards further north hard greywacke occurs on the shore, and at 150 yards further north chert beds are finally visible.

Mr. Fox gave this section in detail. He describes the limestone near Haltonquay as

> "of a dark bluish tint, weathering on the exterior to a rusty brown; under the microscope thin sections show that it is granular, and mainly foraminiferal in character, containing *Endothyra*, *Trochammina*, *Dentalium*, and *Nodosinella*. The forms of *Endothyra* resemble those in the Lower Culm limestones of Canonsleigh, N.E. Devon. The cherty rock occurs in regular beds, two inches and upwards in thickness. It is dark, or black, hard, compact, finely laminated, and with numerous quartz veins. . . . It is composed of radiolaria so numerous as to be in contact with each other. The best exposure of this chert is about 70 yards south of the old limekiln of Chapel Farm. North of the Chapel Farm limekiln cherty rocks again appear; they are so closely traversed by quartz veins as to become of a bluish grey tint, but in spite of this their radiolarian characters are still recognisable in thin sections."[1]

The termination of the Culm rocks eastward is probably determined by a fault (concealed by the alluvium of the Tamar), which in its southerly prolongation shifts the Pentillie Culm greywacke outlier to a more northerly position on the Devon shore. Toward Haymarsh this line of fault is suggested by marshy ground.

By the road to Haltonquay, at about 350 yards east of Heathfield, a well was sunk to a depth of 22 feet in dark shale, but this cannot be taken as evidence of Lower Culm, as in the greywacke series in this vicinity, and locally elsewhere, greywacke or grit seems to be only represented by occasional thin beds in dark shales. This difficulty in distinguishing dark slates or shales in the Lower Culm from dark slates or shales in the greywacke series and from dark slates in the Upper Devonian is apparent near Dunnerdake and on Crendle Down, as already mentioned. The same difficulty is experienced at Gappagh, south of Chudleigh, in Sheet 339, and elsewhere.

On the west of the faulted patch of Upper Devonian cherty beds of the Lower Culm occur north of Heathfield; they are not shown on the map, as no boundary could be drawn until their relation to the radiolarian Lower Culm rocks of Smeaton described by Mr. Fox[1] could be ascertained.

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[1] *Trans. Devon. Assoc.*, vol. xxviii., 1896, p. 786.

The Devonian inlier east of Amytree is surrounded by the Culm greywacke series with which it is in faulted contact on the west.

In the north of Amy Down a small patch of hard dark shaly beds and chert is exposed in a quarry. This inlier completes the evidence of Lower Culm in the St. Mellion tract in Sheet 348.

Outliers.—The original extension of the Lower Culm Measures is proved by the outliers near Tamerton Foliott. The largest of these is nearly four miles south-east of Painter's Cross and consists for the most part of hard dark cherty fragments forming a thin top soil, but near its south-eastern extremity the chert beds are exposed, and (at Tor Rock) seem to rest on dark shales. There is evidence of a band of decomposed igneous rock in the Upper Devonian along the southern boundary of the outlier.

The smaller outlier caps the summit at a quarter of a mile south of Tamerton Foliott. It does not extend much beyond the quarry in which dark even-bedded quartz-veined chert beds, much contorted, are exposed. The specimen submitted to Mr. Teall (slide No. 3,152) is described as "banded chert traversed by quartz veins. Under the microscope some layers are full of traces of radiolaria."

At half a mile east of Whitleigh Hall, a mile from the small outlier, and in line with the direction of the larger one, a patch of exceedingly disturbed black shales or slates is cut through in the high road. The possibility of the occurrence of a Culm outlier here at once occurred to me, but as it is at Wheal Whitleigh lead and silver mine, and probably along or close to the lode, in the absence of more conclusive evidence it is not indicated on the map.

Worth considered this exposure as on an anticlinal which Prof. Phillips supposed to exist near Whitleigh. "Here," he says, "so far as lithological characters go, both Carboniferous and Devonian slates may be represented. There is a massive badly cleaved quartzose slate, dipping 45° south-west; a massive well-jointed drab slate, nearly horizontal; some ferruginous slate; and some black rotten slate. The southerly dips are at the southern end of the cutting; at the northern end the dip is north-west."[2]

MIDDLE CULM MEASURES.

These strata consist of more or less felspathic sandstones, or greywackes, and of dark shales. The greywackes vary in grain, but in this district cannot be regarded as really coarse-grained, and are never conglomeratic as in the corresponding rocks in Ugbrooke Park, &c. The dark shales as before stated are difficult to distinguish from Lower Culm and Upper Devonian where the greywacke intercalations are few and far between and the surface evidence is obscure.

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[1] *Ibid.*, p. 785.

[2] *Ibid.*, vol. xxi., 1889, p. 279.

At Crist hard dark micaceous beds of greywacke interbedded with shales containing plant remains are exposed, also interlaminated bands of shale and greywacke associated with false-bedded greywacke, exhibiting anticlinal structure. To the south of Crist thick beds of greywacke and laminated greywacke and shale were observed in a disused quarry. These rocks are faulted against Upper Devonian in the valley south of Crist by an east and west dislocation, shifted by a nearly north and south fault, and are thrown against the Upper Devonian and Lower Culm by a south-easterly fault, at the north-east end of Crendle Down. Their occurrence on Herod Down is proved by surface-stones.

North of Herod Down tough beds of greywacke interbedded with shales are exposed, dipping south at the south end of Bramble Wood.

In quarries on the margin of the woods north of Bramble Wood the greywackes are also seen. In one of these pits, on the south of Oakpark Wood, blue-grey shaly mudstones are associated with the greywackes which are partly laminated and false-bedded and also exhibit fine interlamination with dark shale. The dip is southerly at 50°.

On the east side of the stream in New Down, at more than half a mile south of the Lower Culm inlier on Amy Down, a quarry exhibits 20 feet of fine-grained tough beds of greywacke on dark shales with beds of greywacke. The dip seems to be easterly. East of Amy Down, near the southern end of the Upper Devonian inlier, the tip from an abandoned manganese mine consists of dark slate or shale and greywacke.

At about half a mile north from Pillaton Church 30 feet of greenish-weathered greywacke (freestone) rests on slates or shales, apparently with beds of greywacke, in a quarry giving a S.15°E. dip of 35°.

In some old pits at about a quarter of a mile north-east of Dunstan undulating dark grey beds of greywacke and shale, with numerous traces of plants (Calamites), are exposed.

At a quarter of a mile north of Crocadon, thick beds of greywacke with shale partings were seen dipping south. At the west end of Ryland's Plantation greywacke associated with buff-weathered shales dip south. North-east of St. Mellion and south of Crocadon blue-grey shales and greywacke exhibiting zigzag contortions are exposed in a quarry. This quarry, or one in Crocadon Wood south of Heathfields, is mentioned by Mr. Fox as containing plant remains and ash beds.[1]

Between Trewashford and Rouse the surface affords no reliable evidence of the nature of the subjacent rock, and it is possible that the patch of Lower Culm at Rouse may be connected with the Lower Culm on the hill feature east of Pillaton and with the patch on the north side of the Polborder Upper Devonian inlier. The Devonian boundaries, however, are reliable.

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[1] *Trans. Devon. Assoc.*, vol. xxviii., 1896, p. 786. The thin interbanded greywacke seams have the aspect of fine ash seams, as in similar seams in the Wearde and Efford greywackes.

The Lower Culm at Rouse ends abruptly at the valley on the east, the opposite slope in Northdown Wood affording ample evidence of the presence of the greywackes which can be traced continuously eastward to the vicinity of Painter's Cross. On the soutn of the Lower Culm ridge east of Pillaton the Middle Culm is not exposed and the continuation of the main fault boundary of the Upper Devonian and Culm may with deflection continue as the boundary between Middle Culm and Upper Devonian, but its more probable direction would be along the south foot of the Lower Culm ridge. At any rate, the greywacke series continues for three-quarters of a mile east of the Lower Culm feature with the appearance of chert beds highly contorted on the south of it. These contorted chert beds occur on the same side of the valley as Northdown wood, and at 100 yards to the north-east a small quarry exposes blackish greywacke part shaly with many traces of plant remains.

The continuity of the Culm is broken by the next valley, about a mile from St. Mellion on the south. On crossing this valley purple slates of the Upper Devonian are evidenced on the slope, and greywacke fragments attest the presence of the Middle Culm on the summit. As already shown Middle Culm is also present on Vinegar Hill south of Painter's Cross in faulted contact with Upper Devonian on the south, but giving place to Lower Culm on the north and east. The absence of evidence renders the relations of the Middle to the Lower Culm north of Painter's Cross equally indefinite.

The sharp projection of Culm at Mount Ararat (in Hornavas Wood) is composed of Middle Culm shales and greywacke, partially exposed with a southerly dip in an old quarry near the south margin of the wood, where their boundary with the Upper Devonian seems to be a fault.

Between Mount Ararat and Crocadon Wood a patch of greywacke and plant-bearing shales is let down by a fault. The quarry in which it is shown is mentioned by Mr. Fox 'at Woodlands near the borders of Halton Wood.' This fault displaces the Middle Culm and Upper Devonian boundary in Halton Wood (on the six-inch map), and seems to bifurcate, one branch cutting off the Culm on the south near Haltonquay, the other crossing the Burcombe Valley and cutting off the Upper Devonian, in the direction of Haymarsh, against dark grey beds of greywacke and plant-bearing shales exposed in quarries on the west side of the valley near Dairymill (on the six-inch map). At Burcombe there is a quarry in dark plant-bearing shales and greywacke.

West of Fursdon dark slates or shales, probably belonging to the Middle Culm, cross the stream valley near a band of igneous rock in the Upper Devonian slates which are purple in one place by the road on the east of a large Upper Devonian slate quarry near this. The dark slates or shales are cut off on the west by a fault bringing in a tongue of Upper Devonian by the stream, under Middle Culm. A little further west a cross fault brings on the Upper Devonian to the north of Heathfield. Just north of Fursdon there might be a small outlier of Culm. The Pentillie outlier and its shifted continuation on the point of land inside the sharp bend in the Tamar consists of beds of grey and dark grey greywacke, weathering brown, and of dark shales. These rocks are exposed in a quarry on the Devon shore, and at Pentillie, and contain obscure plant traces.

The presence of the higher horizons of the Lower Culm at Herod Down and near Haltonquay, not elsewhere represented, points to the extension of that series over the area north of Plymouth and to its partial removal, at least, by denudation prior to the deposition of the Middle Culm.

In the Chudleigh and Ashburton areas (Sheet 339) a somewhat similar unequal representation of the Lower Culm, but in a much lesser degree, may be traced; yet it is in the coarser beds of the Chudleigh and Newton area that we obtain in the occurrence of conglomerates with worn chert fragments the direct evidences of the denudation of the Lower Culm and not in the St. Mellion greywackes, where the Lower Culm has been only partially spared by that denudation.

Although I am inclined to think that the Lower Culm is itself unconformable to the Devonian direct evidence of this is not forthcoming, but as to the unconformity of the shales and greywacke to the rocks on which they rest there can be no doubt, and the destruction of volcanic rocks during their formation, if not certain, is highly probable.

CHAPTER VI.

NEW RED SANDSTONE PERIOD.

De la Beche, in the chapter on the Red Sandstone series in his Report, points out the occurrence of "a porphyritic rock . . at Cawsand . . . which in general aspect resembles some of the igneous rocks associated with this series in the neighbourhood of Exeter and Tiverton." He seems to have connected its eruption with the intrusive dykes of igneous rocks in "the greywacke red sandstones and slates" [Staddon grits] in the coast to the east, and adds:—"Though unable to adduce direct proof, we are inclined to refer this porphyry, from its general character, to the date of the lower part of the red sandstone series."[1]

The direct proof was supplied in 1867, when Pengelly described a patch of conglomerate on the beach at Cawsand close to the trap (to which his attention had been directed by Mr. Reading), as "having the colour and general characters of the Torbay Trias."[2] Worth, in 1886, noticed the presence of trap as well as Devonian limestone, grit, &c., fragments, in this "low flat beach reef" of breccia. As further evidence of the former presence of New Red rocks, he cited the following: The occurrence of an untravelled block of breccia of Triassic aspect, weighing probably four or five tons, on the beach at Drake's Island; the presence of veins of fine red sandstone in the joints of the Plymouth limestone, wholly differing from the true Devonian sandstones; the resemblance of the 'head' between Cawsand and Picklecombe to unconsolidated Triassic breccia as being suggestive of the redeposition of Triassic *débris*.[3]

He further cites the occurrence of New Red materials dredged from the Channel bed off the Lizard as evidence of a submarine outlier.[4]

Worth pointed out the evident connection of the patch of igneous rock near Withnoe with the Cawsand trap. To these the survey of the district enables us to add a third mass (at Bridgemoor, on the six-inch map) half a mile north-east of Withnoe. The intrusive nature of the two smaller patches is clear, but the origin of the Cawsand rock is not so certain.

Worth describes two slides from the Cawsand rock, the one earthy, the other compact in texture, assigning to them the name mica porphyrite,[5] which he subsequently abandoned in favour of the term mica-andesite in a paper in 1891,[6] in which he describes four varieties of the Withnoe rock collected within four or five yards from the large quarry, and showing "a well-marked unmistakable passage from what may be termed a rhyolitic pitchstone in the inner portion of the dyke to a trachytic quartz-felsite in the outer."

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[1] 'Report on the Geology of Cornwall,' &c., pp. 211, 212.

[2] *Trans. Devon. Assoc.*, vol. ix., p. 418.

[3] *Trans. Roy. Geol. Soc Corn.*, vol. x., p. 233.

[4] *Quart. Journ. Geol. Soc.*, vol. xlii., 1886, pp. 313–315.

[5] *Trans. Devon. Assoc.*, vol. xix., 1887, p. 493.

[6] *Trans. Roy. Geol. Soc. Corn.*, vol. xi., p. 341–345.

Worth considered the Cawsand rock as a rule most similar to the Pocombe rock, "though less crystalline in texture, whilst some of the grey micaceous patches are hardly distinguishable in hand specimens from that of Killerton."[1]

There are two quarries in the Withnoe mass—a small one on its border by the road to Withnoe, and a large one on the Down above, which has been extensively quarried for road metal. In the small quarry two varieties are shown, the one compact and with marked rhyolitic character, the fluxion lines being approximately vertical, the other rubbly and paler in colour with prisms of felspar visible in places. In the large quarry the fluidal banding is beautifully shown, and in part, apparently near the outer margin of the dyke, there is an appearance of flaky bedding with sharp undulation. Near the entrance to the quarry smooth round spheroidal bosses are noticeable here and there on the quarry face; they seem to be due to local conchoidal fractures. In both quarries grey and buff tints are present, but the rocks are for the most part mottled buff, yellow, and red. It is difficult to obtain a large specimen owing to the numerous and irregular joints by which the rock is intersected.

The Cawsand mass is exposed in quarries near its northern and western margin, and forms a causeway on the coast representing the old beach platform. The rock is of a pale pink and red colour mottled grey and with pale green and buff patches. It usually presents a rubbly aspect, and the compact varieties and fluidal bandings are much less pronounced than in the Withnoe dyke. The quarry near its western margin affords the best section. Here the rock has an appearance of nearly vertical bedding owing to a north-westerly system of joints ten feet or more apart. These are crossed nearly at right angles by a system of joints averaging four and a half feet apart. The rock shows signs of rhyolitic structure in places, and is much peroxidated. Worth figures a rudely columnar structure visible in the rock on the Cawsand beach reefs at full ebb-tides. Very hard rubbly rock is exposed at the head of a gorge by the fort on the south-east of Maker Farm, and seems to rest on grey ashy-looking Staddon grits split into large blocks in places by irregular joints. Near No. 4 Redoubt even-bedded flaggy grits are exposed in the vicinity of the trap.[2]

The south-western margin of the Cawsand rock is a fault which coincides with the abrupt termination of the beach reefs in a low vertical wall along which adherent traces of friction breccia may be seen. Prolonged inland this Cawsand fault is concealed by valley deposits up to Coombe, where it brings the Staddon grits in contact with the Dartmouth slates. By the road to Cawsand, at 170 yards from Coombe and not far from the margin of the igneous rock, an exposure of fine red gravel of local Devonian fragments, angular, subangular and well-worn, in a comminuted earthy matrix of similar materials with large unworn fragments of the trap, was observed. If of New Red age, which its appearance strongly suggests, it would appear to dip off the trap. Occasional worn grit surface fragments were noticed along the northern border of the trap, which might be relics of a fringing mass of breccia removed by denudation. On the coast the beach reefs of trap, intersected by numerous irregular joints, terminate irregularly on the north (between Sandway Point and Sandway Cellar on the six-inch map). Near their termination fluxion lines suggest a low south-westerly dip. Between the trap reefs and the reefs of Staddon grit there is an interval of sand through which the low reefs of breccia project in places. At low-water-mark the space thus occupied is about 40 yards, widening toward the base of the cliff of Head. No actual contact between the breccia and the trap is visible, but the reef of the former appears to be indurated and to dip S.20°W. toward the trap where nearest to it toward low-water-mark, and it seems highly probable that the breccia underlies the trap.

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[1] *Trans. Roy. Geol. Soc. Corn.*, vol. x., p. 236.
[2] *Ibid.*, p. 235.

The breccia contains fragments of crinoidal limestone, of Staddon grits, quartz, and trap, mostly subangular, but occasionally rounded. The stones are larger and more rounded for 20 yards outward from the irregular junction of the breccia with the Staddon grits. The Staddon grits have a high south-westerly dip, and the breccia dips off them at a low angle without any signs of faulting.

From the above evidences I am inclined to regard the Cawsand rock as in part at least a lava flow, but the presence of fragments of the igneous rock in the breccia somewhat militates against this view. There are fragments in the breccia of the Crediton valley, near Spencecombe (Sheet 325), and elsewhere, which seem macroscopically very similar to the Cawsand and Withnoe rocks.

From the examination of samples obtained by Mr. A. S. Allen, of the Marine Biological Laboratory, Plymouth, in dredging in order to investigate the fauna and bottom deposits near the 30 fathom line, between the Eddystone grounds and Start Point, Mr. R. H. Worth considered that Triassic rocks occur *in situ* in the vicinity of the Eddystone and the Hand Deeps to the west. Among the varieties enumerated are 'conglomerates, coarse red micaceous sandstones, fine red jaspideous sandstone as well as a red felsite and a variegated felspathic trap.'[1]

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[1] *Trans. Devon. Assoc.*, vol. xxxi., 1899, pp. 364–366.

Petrological Notes.

BY DR. J. S. FLETT.

The Cawsand porphyry is dark red in the hand specimen, mottled with grey and white patches and turning pale grey on the weathered surface. It shows many small glancing scales of black biotite, and a few pseudomorphs of kaolin after idiomorphic porphyritic felspar, in a fine grained red matrix which is free from fluxion banding. Under the microscope the biotite is well crystallised, but frequently has suffered corrosion, resulting in a deposit of dusty black iron oxides upon its surface. Its pleochroism is marked, the colours ranging from dark brown to pale clear yellow. The felspars of the first generation are entirely kaolinised. There is no porphyritic quartz, but small corroded quartz xenocrysts derived apparently from the adjacent sandstones may be found in some of the slides. The groundmass is impregnated with secondary iron oxide, mainly as minute scales of hæmatite; it consists essentially of orthoclase felspar in small irregular prisms and shapeless allotriomorphic masses; between these there lies a very small amount of interstitial quartz. Zircon, apatite, and magnetite all occur as accessories in small but well-formed crystals.

The quartz is probably in part secondary, but some of it may be original. The rock belongs clearly to the orthoclase porphyries or orthophyres, and is unlike any of the intrusive masses of Western Cornwall, while it bears a very close resemblance in many respects to the orthophyres of the Exeter district (*e.g.* Killerton) as these have been described by Dr. Teall.[1]

The Withnoe rock belongs to a distinctly more acid type; one variety of it contains many corroded phenocrysts of quartz which are remarkable for the perfection with which they show the rhombohedral cleavage. The porphyritic felspars are numerous, large and highly idiomorphic. Often they are partly kaolinised, but in other cases they are perfectly clear and fresh, having much of the character of the sanidine of recent and Tertiary lavas. Some of them have a very small axial angle, while in others it is 120° or thereabout; the optic axial plane is always perpendicular to the plane of symmetry; hence they may be regarded as a limpid variety of ordinary orthoclase. Biotite is abundant, and resembles that of the Cawsand rock, but is usually less corroded and blackened. The matrix is a micrographitic mixture of orthoclase and quartz in small irregular grains. Plagioclase is to be found only in very small quantity. Zircon and magnetite are present also, and apatite appears in rather large crystals of violet-grey colour. This may be regarded as a very fresh and typical quartz porphyry.

The fluxion-banded or rhyolitic varieties of the Withnoe porphyry have a very fine-grained matrix similar to that above described, but less quartzose and containing also small crystals of biotite of a second generation. This matrix has perfect fluidal structure and the bands are wavy or contorted, giving a damascened appearance to the hand specimens. Porphyritic quartz does not occur in these rocks and felspar is not common, but idiomorphic biotites, sometimes slightly blackened by corrosion, abound, and their crystals are often bent by the fluxion movements of the viscous matrix.

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[1] 'Geology of Exeter,' p. 78, *Mem. Geol. Survey*, 1902.

CHAPTER VII.

POST TERTIARY.

Of the long interval between the accumulation of the earlier New Red rocks and the latest stages in the sculpture of the present contour we have no certain records in this map. An apparently fluviatile deposit retained in hollows dissolved in the surface of the limestone plateau of the Hoe, noted by Dr. Moore in 1841, and subsequently described by Worth, is probably the earliest deposit in the district, and may be of Tertiary age.

The ossiferous fissures in the limestone are usually filled with earthy clay of later date. Of raised beaches there are abundant signs at the base of undercliffs of Head from a foot or two to fifteen feet above high water, and many of these, if exposures allowed the upward slope of the old beach platform to be seen up to the foot of the old cliff, may well have reached from twenty to thirty feet. The Hoe raised beach first recorded by Hennah in 1817 has been exposed from time to time by blasting operations in quarrying and road-making. The records of these exposures agree in assigning a height above the present beach of from 15 to about 40 feet. Discrepances in level are probably due to the slope of the old beach platform being exposed at different heights. The occurrence of Cawsand felsite fragments in this beach was noticed by De la Beche[1]: their preponderance and the presence of an igneous boulder of similar character to the schalstein of Drake's Island were noted by Worth.

Commenting on this circumstance,[2] the latter observer advocated the connection of Drake's Island with the Mount Edgcumbe coast by a partially tidal reef during the formation of the beach, and considered that the deep trough (descending rapidly from 6 to 14 or 15 fathoms) which, with a breadth of 200 yards, occurs in the intervening half mile of water-way between Drake's Island and the Hoe, could not then have existed.

Mr. J. C. Inglis, in 1877,[3] in a paper on Plymouth Sound, illustrated by a chart showing the bottom contours in fathoms below low water, described this channel thus:—"A deep and comparatively narrow trough extends from between Mount Batten and Drake's Island, where it abruptly commences, in the rear of the island and along the Hamoaze as far as Saltash Bridge. . . . In two places the depth is over twenty fathoms at low water, viz., at Devil's Point [22 fathoms] and off Eastern King [25 fathoms], the deepest points in the Sound. Before the twenty-fathom line is reached we have to go two and a half miles outside the Breakwater."

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[1] 'A Geological Manual,' pp. 156, 157, second edition, 1832.

[2] *Trans. Roy. Geol. Soc. Corn.*, vol. x., p. 204; *Trans. Plymouth Instit.*, 1885.

[3] 'Plymouth Sound—its Tidal Currents,' *Trans. Plymouth Instit.*, 1877.

He then points out the resemblance in the different deep estuaries on the south coast of Devon and Cornwall, and points out that the depression at Plymouth "has all the peculiarities of a true 'rock basin,' for the narrower and deeper portions occur just in those places where the erosive power of ice would have been greatest, and as the valley opens out the basin shallows."

The chart shows that the deepest part of the channel between Drake's Island and the Mount Edgcumbe coast ('The Bridge') is under three fathoms. Immediately north of this ledge is the six-fathom line which encloses the deep trough. The soundings, however, do not enable us to arrive at the real contour of the rock bottom owing to overlying deposits. To account for the Cawsand felsite and Drake's Island rock in the Hoe raised beach, it is necessary to assume with Worth that this deep channel did not then exist, or to invoke coast ice, which has elsewhere (Saunton, North Devon, &c.) been instrumental in stranding erratics on the raised beach platform. In 1889 [1] Worth described the section of the rock valley of the Tavy, where the South-Western Railway Bridge spans it, calling particular attention to a layer of gravel and boulders (some of which he referred to a source 15 miles off up stream) lining the rock bottom under 70 feet, or more, of mud.

This is also referred to by Mr. T. Codrington in his paper on submerged rock valleys,[2] in which he also mentions the occurrence of similar deposits on the rock bottom at Saltash Bridge, in the Coombe Lake valley north of Saltash, and at Millbay Docks. He gives many examples of sections of the Tamar and its tributary rock valleys. With the bottom deposits of clay and stones, Mr. Codrington correlates the stream tin gravels in the western rock valleys, referring both to the glacial period and regarding their formation as anterior to the raised beaches, not finding the reasons for the contrary opinion adduced by me in 1879 [3] convincing.

In 1898 Mr. R. H. Worth entered the lists with a paper on 'Evidences of Glaciation in Devonshire.' [4]

He gives many sections across the rock valleys, ten being in this map, in support of the theory of glacial erosion, and regards all stony clays encountered lining their bottoms as boulder clay. He finds the infinitesimal fall of the rock bed of the Tamar, which is almost level for over two miles above Saltash, an additional argument against fluviatile erosion. He compares very aptly the constrictions and widenings in the rock valley of the Tamar to valleys on Dartmoor, which above their narrow parts have been ancient lakes or tarns.

Glacial conditions are assumed to have prevailed during an elevation of at least 180 feet, and the rock valleys to have been scooped out, subsequent to the Hoe raised beach, but before the raised beaches found at lower levels, which are referred to a succeeding subsidence to 30 feet below present level, when the "glacial clays" were deposited in the estuaries After this an upward movement of at least 80 feet, attended by the removal of the boulder clay (glacial conditions having passed away), permitted forest growth, entombed in the following subsidence when the sea attained its present level and the rock valleys were filled with silt and mud.

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[1] *Trans. Devon Assoc.*, vol. xxi., pp. 276, 277.

[2] *Quart. Journ. Geol. Soc.*, vol. liv., 1898, pp. 265-268.

[3] 'Post Tertiary Geology of Cornwall,' privately printed, and articles in *Geol. Mag.*, 1879.

[4] *Trans. Devon. Assoc.*, vol. xxx., pp. 378-390.

In 1900[1] Mr. R. H. Tiddeman showed that the raised beach on the Gower Coast was Pre- or Interglacial. That when the sequence of overlying deposits is complete they preserve the following ascending order—A lower Head traced to connection with bone beds in the limestone caverns—Glacial drift with rounded stones, not of strictly local derivation—Later deposit of Head.

Messrs. Muff and Wright have shown[2] that the 12 to 15 feet raised beaches of the south coast of Ireland are pre-glacial (in a relative sense);

that they are overlain by Head identical in character, having regard to the different sources of derivation, with that on the Devon and Cornwall coast; that both are covered by boulder clay, which rests in places directly on the old beach platform, with accompanying glacial striation; and that the boulder clay is in places overlain by an Upper Head, proving the resumption of similar conditions at the close of glaciation to those which had preceded it. They regard the excavation of the rock valleys of that coast as anterior to the raised beach period.

If Mr. Worth is right in regarding the Hoe raised beach as evidence of a distinct and long prior subsidence to that which led to the formation of beaches found at lesser elevations, then the latter and overlying Head can only be assumed to correspond to the Upper Head of the Irish coast sertion. We here assume that there are not two sets of raised beaches on this coast, the exceptional height of the Hoe beach being ascribed partly to exceptional opportunities of observation, partly to a different configuration of the Sound.

I think Mr. Worth is correct in referring the excavation of the rock valleys to the elevation of the Hoe raised beach during which the coast Head accumulated. During the succeeding depression forest growth took place not only on the present foreshore but far beyond it, and the relics of submerged vegetation are merely the results of an oscillation by which, as advocated by Professor James Geikie, the tree growth was able to advance for a time prior to its final submergence.[3] The probability that the deep depressions in the rock valleys and at their mouths had at some time during these movements formed lakelets is worthy of consideration. What part glacier ice could have played in their formation, as suggested by Mr. Inglis, it is difficult to conceive in view of the sharp bends in the Lynher estuary near Sheviock, and the Tamar near Pentillie, and the extreme sinuosity of the channel between Gunnislake and Calstock, unless such agency were confined to the channels already marked out by fluviatile erosion, and not sufficiently powerful to override them. Striated stones do not appear to have been detected in the deposits near Weir Head and Rumleigh on the Tamar (north of this map), regarded by Messrs. Codrington and Worth as boulder clay, and in the stony clays sometimes found in the bottom of the rock valleys. As regards the general configuration in which these channels are but the final deep cuts, the slow waste of previous ages has left no direct record of ice action. The deposits on the Hoe are practically the only ones on the surface not directly connected with the actual drainage lines. The oldest river deposits in this map are probably not anterior to the raised beach formation.

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[1] *Rep. Brit. Assoc.* Trans. p. 760. Compare with the three lower members of this succession the section on Greenway Cliff near Padstow. *Trans. Roy. Geol. Soc. Corn.*, vol. x., p. 58.

[2] Scientific Proc. Roy. Dublin Soc., vol. x., 1904, pp. 250-324.

[3] *Geol. Mag.*, 1881, pp. 131-134.

The boulders of quartz and of felsite or of diabase found on the surface occur where thick veins or interlacing strings of quartz penetrate the slates, and through the harder parts of some intrusive sills or dykes of igneous rock resisting surface weathering and gravitating down the slopes, but no proofs of erratics have been obtained. North of Liskeard, in the valley east of Tremabe, boulders of greenstone occur, and are said to be encountered here and there is ploughing the fields in the vicinity. The Gunnislake granite is exposed in the Tamar valley, and river ice flotation is more than probable during the elevation that succeeded the old beach formation. One can only wish that direct proofs of ice action may be found to corroborate the origin confidently assigned by Mr. Worth and with less certainty by Mr. Codrington to the relics of stony clay found on the rock valley bottoms.

Mr. Codrington[1] has in my opinion shown the strong probability of a correlation of the submerged valley stony clays with the later boulder clays, and has adduced evidence tending to prove that the rock valleys (in the south-east of England) were excavated since the older boulder clays, which chimes in very well with ice flotation on the coasts during the raised beach formation. He suggests the concealment of a deeper rock channel by blue clay in the Sound between the deep depression and the Breakwater.

Older Deposits on the Limestone Plateaux.

These have been examined and described by Worth.[2] Midway on the Hoe plateau at an average height of 100 feet above mean tide extensive excavations disclosed a bed of clayey earth four or five feet deep in places, with pebbles ranging from "very small size up to boulders a dozen or more pounds in weight scattered through it," and containing "patches of white and red clay." The pebbles are chiefly quartz with granitoid rocks, quartz schorl rock, and a few of a dark hard slate; partially worn limestone fragments also occur.

"With the clay are small veins of sand tending downward to" a subordinate mass of white, drab, cream-coloured and red fine siliceous sand, probably filling a fissure in the limestone to a depth not ascertained. The white clay resembles Bovey clay and contains very few pebbles.

Sand largely mixed with pebbles was found in the founda-

[1] *Quart. Journ. Geol. Soc.*, vol. xxxiv., 1878, pp. 456–458.

[2] *Journ. Plymouth Instit.*, vol. v., 1875, pp. 472–474.

tions of Elliot Terrace, adjoining the Hoe. "At the south-eastern corner of the Hoe . . . the fissures in the rock contain pebbles precisely similar in character to those above."

In the adjacent map (349) "at Deadman's Bay may be seen the remains of a large 'pocket' in the limestone, one side having been worked away, which was at least sixty feet in depth, and which was filled with clay and pebbles precisely similar to the white clay and pebbles of the Hoe."[1] In a subsequent paper in 1888,[2] Worth states that these deposits have no connection with the Hoe raised beach, that they have not yielded a trace of organic matter except a fragment of wood, probably birch, and that the stones are mainly of Dartmoor origin, belonging rather to the Tavy watershed than to that of the Plym. He then describes a deposit of well worn stones on the northern slope of Catdown 60 to 70 feet above datum, which from the number of flints, 40 per cent., suggests relics of Tertiary gravels.[3]

The first palæontological discovery recorded in connection with the Hoe was in 1808, when there was found in a bed of fine sand in a fissure "at least 50 feet above high-water-mark," unconnected with the raised beach, "one side of the jaw of some nondescript animal." [4]

Bone Caves and Fissures.

In 1838 or 1839, Dr. Moore records [5] the discovery of bones on the top of the Hoe raised beach ten feet beneath the soil. these included: Molar and part of jaw of a young elephant; femur of rhinoceros; maxillary bones with teeth of a bear; long bones; fragments of jaws of horse with teeth; deer's jaw with teeth; vertebra of a whale, much worn, as were also some bear's tusks. Worth[6] attributes the position of the bones to derivation from a pre-existent fissure. He also mentions bones of hyæna in the Plymouth Institute Museum from the Hoe fissures; and the discovery of mammoth teeth and of a rhinoceros tooth (found by Mr. Hearder) on the present beach under the Hoe. In 1844, close to the dividing wall between the Hoe and limestone quarry, at about 20 feet above the path under the Hoe, two elephant tusks (*E. primigenius*) were unearthed (by Mr. Edyvean), one being over six feet long and two feet nine inches in girth at base.

In the Stonehouse limestone an ossiferous cavern is said to have been discovered about 1835, and another "while the works of the Great Western Docks were in progress." The most important, situated in the southern face of a quarry on the Battery Hill spicuous from the hill top to the quarry floor, a depth of 60 feet or more, running along the line of north and south nearly perpendicular joints in the limestone, and subsequently turning to the north-east. This cavern and its ramifications was investigated by Worth, 1879-1882.[1] Its width varied from two to twelve feet, and it was filled with earth partly clayey. In the fissure and side chambers communicating with it obscure osseous fragments and imperfect bones were scattered. A comparatively numerous proportion of teeth enabled the following identifications to be made: Rhinoceros (*R. tichorhinus*), horse, hyæna, bear (*Ursus ferox*), fox, wolf, cat, dog, probably boar, hare, black rat—one individual of each, only. Teeth of sheep or goat, bones of several species of deer, including teeth of two reindeer (*C. tarandus*); of ox, *Bos primigenius, B. longifrons,* and perhaps *Bison priscus.*

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[1] Similar pebbles probably occur in fissures in the limestone of Mount Batten. See Worth, *Journ. Plymouth Instit.*, 1879.

[2] *Trans. Roy. Geol. Soc. Corn.*, 1888, 'Detrital Deposits Associated with the Plymouth Limestone.'

[3] Mr. Jukes-Browne refers the limestone plateaux of the Torquay area to Eocene planation. *Quart. Journ. Geol. Soc.*, vol. lxiii., p. 106.

[4] *Monthly Mag.*, vol. xxvi., p, 191 ; *Trans. Devon Assoc.*, vol. ix., p. 428.

[5] *Rep. Brit. Assoc.*, 1841 ; *Trans. of Sect.*, pp. 62–63.

[6] *Trans. Roy. Geol. Soc. Corn.*, 1888, Detrital Deposits Associated with the Plymouth Limestone.

Rhinoceras tichorhinus.
Ursus ferox.
Hyæna spelæa.
Canis lupus.
C. vulpes.
C. (small variety).
Felis catus.
Cervus elaphus.
C. tarandus.
C. capreolus (?).
Bos primigenius.
B. longifrons.
Bison priscus (?).
Equus fossilis.
Sus scrofa.
Ovis or Capra.
Lepus timidus.
Mus rattus.
Fragment of dermal skeleton of a fish (? sturgeon).

In the same locality, but in a disconnected fissure investigated by Spence Bate in 1865, probably since quarried away, remains of tichorhine rhinoceros, horse, ass (*Asinus fossilis*), ox (*Bos longifrous*), deer (small species and *Cervus elaphus*), were obtained.

Worth was informed that, in 1861, during "the construction of the battery adjoining the grounds of the General's house, Mount Wise," fissures were revealed in which bones were found. Only remains of deer (*Cervus elaphus*) and of horse were mentioned.[2]

Raised Beaches and Head.

Hennah's observations of the Hoe raised beach date from its exposure in the cutting of a road round the Hoe in 1816. Some years later he wrote: "In many parts of the Hoe, on the declivity toward the sea, about fifteen or twenty feet above high-water-mark, and in other places also, there is a bed of sand and waterworn pebbles, varying in thickness from less than a foot to that of two or three cemented together in layers," &c.[2]

In 1832 De la Beche remarked, "At Plymouth and the neighbouring coast there are remains of a beach, of which the maximum elevation is about thirty feet above high-water-mark, sloping gradually to the sea." He then gives a diagram of the Hoe raised beach. The only shells he saw were pieces of *Patellæ* and small *Neritæ* [Mr. Reid suggests probably *Littorina obtusata*]; but adds "Many hundreds were found in a cavity of the limestone filled with sand and thrown away by the quarry men. Beneath the citadel the sand is composed of fragments of shells." The section figured by him seems to have been actually seen, as he says, "is exposed by blasting the rock, the limestone being taken away in great quantities." The beach was shown under a loose breccia of unworn limestone fragments which masks a low cliff to the foot of which the beach does not extend. The same superficial detritus was shown in an irregular hollow in the limestone on the slope above, and is said to be devoid of pebbles and sand, and to be precisely similar to the infilling material of the ossiferous clefts of Oreston. From this he inferred the existence of the extinct mammalia when the beach was raised, and prior to a long period of surface waste. The raised beach pebbles "consist of limestone, slate, red sandstone, reddish porphyry," which occurs in place in another part of Plymouth Sound,' and of constituents of the Grauwacke [Devonian] series.[1]

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[1] *Trans. Plymouth Instit.* and *Devon and Cornwall Nat. Hist. Soc.*, 1881 *Trans. Roy. Geol. Soc. Corn.*, 1882.

[2] *Journ. Plymouth Instit.*, 1879.

[3] 'Succinct Account of the Lime Rocks of Plymouth,' p. 58.

In 1839 J. C. Bellamy described the beach[2] at the Western Hoe as "about 20 feet in depth," and "about 50 feet above the present sea," in cemented layers of sorted sediment varying "from very fine sand to tolerable-sized pebbles."

Dr. Moore, in 1841, said that the raised beach had been then almost entirely removed by the extension of the adjacent quarry. He gives the area occupied by it as 100 feet in width and 40 feet in depth (which probably indicates the height of the raised beach cliff), and its height at base as 35 feet above high-water spring tides. Among the mammalian remains then recently discovered on its upper part, ten feet below the surface, "caudal vertebræ of the whale, and the lower valve of a large oyster," are mentioned.

In June, 1884, alterations in the road led to the exposure of the eastern part of the beach at the junctions of the two divisions of the Hoe. The exposures were carefully noted by Worth, who gives the following section:—

	Ft.	in.
Under the turf—Head of earth mixed with angular stone rubble...	1	6
Sand and very small pebbles in about eight horizontal layers ...	2	6
Nine alternating layers of pebbles (averaging 1 to 2 inches in length) and sand	3	10
Large blocks chiefly limestone with rounded edges, up to 2 cwt....	2	0
(One boulder being similar to the igneous rock of Drake's Island.)		
Rock shelf sloping seaward.		

The materials of the beach, especially in the lower layers, were cemented by carbonate of lime into a rock so hard in places that it had to be removed by blasting. Whilst he found the constituents of the modern Hoe beaches to be chiefly limestone, in the raised beach above the basement boulder bed the occurrence of that rock was exceptional, pebbles of red and grey grit being more frequent, of slate occasional, of the Cawsand felsite most abundant; the same proportions equally applying to the finer constituents of the beach.

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[1] 'Geological Manual,' second edition, 1832, pp. 157–159.

[2] 'Natural History of South Devon,' pp. 114, 115.

Among the shells in the beach he noted whelk, limpet, oyster, cockle, and periwinkle.

In no other place on this coast is there a record of raised beach corresponding in height to that of the Hoe, but whereas here exceptional facilities were afforded, by artificial excavation, for tracing the raised beach up the higher part of its sloping platform beneath the Head, similar aids to investigation might well reveal traces of raised beach at corresponding heights on the platforms now covered by Head between Picklecombe Point and Cawsand, on the Downderry Coast and at Hannafore Point, south of Looe.

To account for the preponderance of materials from the Cawsand coast in the Hoe raised beach, in addition to Worth's theory it is necessary to assume that the outflow of the Tamar was either dammed by beach sand or shingle or otherwise rendered ineffectual to interfere with the deposition of these materials on the south side of the Hoe, so that the inset of the tides on that part of the coast would be direct, and in the bight of a narrowing channel. We have failed to find any indication of the insulation of the Hoe during the Raised Beach period, and it is very doubtful if the sea had free access to the sites of the present estuaries of the Plym and Tamar during that period.

Near Mount Batten pier there is a trace of coarse consolidated old beach sand. The lower isthmus connecting Mount Batten with the higher ground on the south and east may have been a tidal reef during the Raised Beach period. It is now covered by a deposit of fine gravel and earthy sand of grit quartz and slate to a depth of from eight to ten feet.

A somewhat similar phenomenon is exhibited in the estuary between St. John's Lake and Millbrook Lake, which but for embankment would now be connected in a tidal flat insulating Southdown Hill. The gentle slope rising upward from this flat tract eastward is composed of brown loam and gravel exposed to a depth of 10 feet in Inswork Brick pits, where it rests on Middle Devonian slates and schalsteins. On the south side of Millbrook Lake the steep slopes of the Staddon Grits give place to a lesser gradient composed of Head, which rests on gravel detritus forming a low terrace near Millbrook Pier, and is seen by the road at the houses east of Anderton to a depth of 30 feet consisting of red loam with grit and slate fragments derived from the Staddon Grits above.

On the Mount Edgcumbe coast, near The Bridge about half a mile from Picklecombe Point, Head forms a fan, opening out from a gulley in the steep slope on the west and exposed in places on the cliffs, where it contains small angular fragments of the local rocks in a brown loamy matrix mixed with sand, and at its base at about 15 feet above high water, occasionally containing pebbles, no doubt relics of 'Raised Beach' which is engraved on the old Ordnance Geological Map near this.[1]

To the west of Picklecombe Point there is a fine section of Head of angular fragments of slate and grit in red loam. At and near its base, from 10 to 15 feet above high water, pebbles of red grit (the local rock), some of large size, indicate the former presence of raised beach materials.

At a quarter of a mile from Picklecombe Point a well-marked terrace of Head commences and extends thence for a distance of a mile and a quarter to Kingsand, forming cliffs of from 10 to 20 feet or more. At the mouth of the stream, at the boundary of Mount Edgcumbe Park, it consists of 15 feet of red loam, with angular and slightly worn fragments of the local grit. At 160 yards or so to the west buff and greenish-grey sand was observed under, and partly obscured by, the Head, at about six feet above high-water-mark. On a little reef projection from 10 to 12 feet above high water, 30 yards further on, red-brown sand with large grit pebbles afforded further proof of old beach material under the Head. In places for about 10 feet upward from the igneous rock beach reef buff and red brown sand may be detected under from 10 to 15 feet of Head, with trap fragments in a loam of such a deep red colour that it presents a very strong similarity to types of certain rubbly New Red breccias.

At Cawsand Pier, north of Penlee Point, the old beach platform is about eight feet above high water, and supports a Head of brownish and greenish loam with angular fragments of the Dartmouth slates. Between Penlee Point and Rame Head, a fringe of Head, in places 20 feet thick, rests on the old beach platform, on which it forms a small detached cone or pinnacle, at a quarter of a mile from the Point. A small pinnacle of Head is also visible on the old beach platform on the east coast of Rame Head, a relic of the accumulation which has here been denuded from the platform, allowing the old cliff to be completely uncovered for 200 yards or more. On the west side of the isthmus connecting Rame Head with the mainland, and for 250 yards northward, the Head has also completely disappeared from the old beach platform. The long strip of Head on which Rame Coastguard Station is situated forms cliffs from 20 to 50 feet in height. It consists of brown loam with angular slate quartz and grit stones, and exhibits an appearance of stratification through the occurrence of impersistent seams of loam of a paler hue. Toward its base the Head is sandy in places, suggesting admixture with old blown sand or beach material. The rock reef platforms are at about three feet above high water.

There is Head in the valleys truncated by the cliffs at Long Sands. The Head at Portwrinkle consists of angular stones of the local rocks in buff and grey loam, and forms a cliff about 20 feet in height, from which the land rises gently northward for 30 to 60 yards, fringing the steeper slopes and passing up the deeper valleys. At the base of the cliff traces of raised beach are visible for a distance of 200 yards. These consist of well-worn slate, quartz, grit, and occasional flint pebbles, mostly small, with a few large subangular blocks of slaty grit, cemented by blackish sand, 18 inches thick in places, which adheres to inequalities in the slate reef platform, at from two to five feet above high water.

At half a mile west of Portwrinkle, a trace of raised beach was noticed at 15 feet above high water, under a small patch of Head. Three small streams intersect the Downderry Head plateau. In the bed of the easternmost of these the angular stones are cemented by blackish sandy matter for about a foot, a probable indication of amalgamation of old beach material with Head. The cliff of Head rises westward to a height of 50 feet, and consists of yellow-brown loam, with local unworn stones. The upward slope of the plateau approaches the 100 foot contour in places. In the gulley near the Seaview Hotel the material in the lower eight feet is finer, and has an appearance of landward distribution, as if shed from an old beach stack. At about a quarter of a mile to the west the section shows loam with numerous stones on two feet of stoneless loam, on six feet of brown, earthy, partly-consolidated, bedded sand, containing numerous pebbles and subangular fragments, mostly small, but rather larger near the base at the level of the present beach. On the west of Seaton, Head caps the cliffs for a quarter of a mile; at its base partially consolidated drab sand, with occasional pebbles and subangular fragments, about two feet in thickness, was seen resting on the old beach platform at about five feet above high water. Near this the Head presents a stratified appearance for four feet from its base.

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[1] In 'Pleistocene Notes on the Cornish Coast between Plymouth and Looe, *Trans. Roy. Geol. Soc. Corn.*, vol. x. p. 63, many of these observations are recorded.

Toward Millendreath Beach, at about a quarter of a mile from East Looe, a patch of Head 30 feet thick forms the cliff, from which it rises to the 100 foot contour. For five or six feet from its base the Head is more or less sandy, through admixture with old beach material, and beneath it the raised beach is represented by from three to four feet of drab-gray sand, with occasional pebbles and subangular stones to within a foot of its base, at five to six feet above high-water-mark, where pebbles are numerous.

The long strip of Head between the Looe estuary and Portnadler Bay is composed of yellowish-brown loam, with local fragments throughout, mostly small. It forms a low cliff, from 10 to 15 feet high, near Hannafore Point, where the material is used for brickmaking. Its upward slope inland probably reaches the 100 foot contour in places. Traces of raised beach (buff sand with pebbles) were observed at its base, at about 360 yards north of Hannafore Point. Near its westerly termination the Head contains large fragments of grey slate.

Looe Island is fringed on the north and east by a strip of Head, which forms a gentle upward slope, and broadens out on the eastern side, where the house is situated. On the north coast, where the Head is about 20 feet thick, and consists of drab-brown loam with fragments of the local slates and quartzites, and quartz, the lower part for five feet is a yellow-brown loamy sand, with boulders of quartzite and occasional pebbles, evidently an admixture with beach material; it rests on the rock platform at about two feet above spring tide high-water-mark. This is confirmed by following the coast eastward to the point where the northernmost patch of diabase occurs; here two or three feet of brown sand with worn stones is visible on the rock platform, at a few feet above spring time high water, under Head, which overlaps and conceals it in the vicinity. On the east coast the Head attains to about 30 feet in thickness, and it is from 15 to 20 feet thick near its termination on the south of the house.

There is a little Head on the old beach platform at about six feet above spring tide high-water-mark south of the fault in Portnadler Bay. On the Hore Stone reef there is a small patch of Head over 100 yards distant from the fringe which caps the mainland cliff. At half a mile to the west a stack of Head rests on an insulated portion of the old beach platform at 30 yards or so from the Head on the mainland cliff. Pinnacles of Head detached from the patch fringing the west side of Talland Bay are noticeable on the foreshore. Near its northern termination fine sand, with a few small pebbles, was observed under this patch of Head, but it may be nothing more than modern beach sand overlapped by a slip of the Head. A low plateau of Head conceals the old beach platform in the centre of Talland Bay.

Patches of the Head, for the most part thin, occur here and there on the Polperro coast, but no traces of raised beach have been seen on the old rock platform, which has been replaned in its lower parts and denuded into an irregular series of islets in its higher slopes on the foreshore. It must also be borne in mind that the raised beach platform was ramified by contemporaneous channelling, in witness of which the relics of raised beach at the base of the cliffs of Head on the level of the present beach, or little above it, at Downderry and elsewhere may be adduced.

Valley Deposits above High-water-mark.

Although the tributary valley bottoms are seldom unaccompanied by alluvial deposits, often occupying a space disproportionately large to the present tiny brooks and rivulets, there is a general absence of deposits marking the earlier stages of erosion. In the tidal estuaries the same general absence is noticeable, and excepting the somewhat doubtful indications at Inswork and Anderton, there is nothing to show that these estuaries were entered by the sea during the raised beach period; we may therefore assume that if they existed such indications have been destroyed in the subsequent deepening of the channels, and that the breadth of the estuaries of that period was not greater than at present.

In the north-east corner of the map terrace features on which no deposits were exposed occur on the east bank of the Tavy, rising from about 40 to 100 feet above the alluvium.

In the West Looe Valley (at Trelawney Mill), between Kiln Wood and Sowden's Bridge, a narrow terrace feature rises from 10 or 12 feet above the alluvium to the 50-foot contour. The deposit exposed by the road consists of from five to six feet of angular and subangular grit, slate, and quartz gravel of small size, except occasional fragments of grit and quartz, in a loamy matrix. Bedding is indicated by the distribution of the stones. A similar feature on which no deposit was exposed marks the same stage of erosion at from three-quarters to a mile above Sowden's Bridge.

In the north-west corner of the map, at Ashford Bridge, a fairly well marked terrace of the Fowey rises from the alluvium to a height of about 20 feet. The remaining signs of terraces all similarly border the alluvia of the valleys in which they occur. No deposits are exposed on them, their occurrence being simply indicated by surface contour, and often apparently rendered indistinct by Head or wash, the same being the probable cause of the upward slope of the terrace features above mentioned. Such contours are seen in the West Looe valley east of Dobwalls and in the Tiddy valley near Venton House.

Broad tracts of flat or nearly flat ground are common at or near the sources of streams or brooks; these have been shown as tracts of alluvium or Head.

Examples are to be seen:—At Rame, at Withnoe, near Manadon north of Plymouth, by the brook between Leigh and Hatt south-east of Pillaton, at

Dannett Wood east of Quethiock, at Trehunsey Bridge, east of Horningtops near Clicker Tor, between Tremabe and Treworgey north of Liskeard south of Twelvewood, west of Dobwalls, &c.

Mr. Codrington refers to the comparatively high ground in which the tributary brooks rise notwithstanding their insignificant length; this is noticeable everywhere throughout the area.

The three head sources of the Stonehouse creek stream rise at heights of 125, 150, and 225 feet above datum, and converge in the basin-shaped depression (south of Pounds on the 1-inch map), in which Stonehouse Reservoir is situated. This depression rises nearly to the 125 foot contour on the north, declining thence to its southern end in a distance of a quarter of a mile about 40 feet (1 in 33). Its maximum breadth is 260 yards on the north, decreasing to 130 yards on the south. The rock bottom is concealed by pale yellowish brown clay, with small stones. At a mile below this depression the rock bottom is 9 feet above low water, and covered with 5 feet of silt.

On the north side of the cemetery near Stoke Reservoir, a flattish tract 150 yards long, and from 20 to 40 broad, slopes from about 120 feet above datum (near the head of the valley) on the west to 80 or 90 at its eastern extremity, whence a tiny brooklet flows southward for about half a mile into Stonehouse Creek. A similar clayey deposit occupies this depression, and has been used for brickmaking.

The resemblance on a small scale borne by these tracts and similar phenomena near Manadon and Treworgey, to the rock basins of the creeks and to such depressions as those of Millbay and of Sutton Pool is striking, with due allowance for the effects of marine erosion in inaugurating and subsequently modifying the latter. In this connection it may be mentioned that the foreman informed me that in sinking Messrs. Polkinghorne's Brewery well, near Bedford Street, Plymouth, 20 feet of yellow clay with stones was encountered on the surface. I am not aware of the occurrence of superficial deposits elsewhere on the Devonian rocks between Union Street and Sutton Pool.

Submerged Rock-valleys and Deposits below High-water-mark.

Messrs. Muff and Wright[1] have ascribed the erosion of these valleys to a period anterior to the raised beach formation on the south coast of Ireland. Although the description of Queenstown Harbour seems to favour this opinion, and analogies to the platform and overlying Head and beach at Great Island are furnished by the deposit on the Mount Batten isthmus, and the occurrences at Inswork and Anderton already referred to, the view here taken is that even if these valleys were tidal during the raised beach period, they were not then deeply trenched, but during the succeeding elevation.

From the papers by Messrs. Codrington and Worth the following facts are gathered, respecting the depth of the rock valleys below low water and their contents:—

River Tavy, at the S.W.R. viaduct, 68 feet, rising abruptly 1 in $1\frac{1}{4}$ to the north bank; bottom deposit stiff yellow clay with small granite boulders thinning out against the sides of the valley, under sand to a maximum thickness of 68 feet.

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[1] *Scient. Proc. Dublin Soc.*, vol. x., part ii., no. 25, pp. 272, 285

Tamerton Lake, at the S.W.R. viaduct, 15 feet.

Coombe Lake (half a mile north of Saltash), timber viaduct, 35 feet; bottom deposit stony clay about a foot thick under about 40 feet of silt.

Saltash Bridge, borings in 1855, at central pier, rock bottom irregular, slopes toward Cornish side 1 in 6, to 76 feet; bottom deposits yellow clay and gravel, gravel, large stones, under 24 feet of mud and silt.

Westonmill Creek, G.W.R. viaduct, 66 feet, under 72 feet of mud; Hamoaze, opposite Weston Mill Creek, 72 feet.

Keyham Lake, at half a mile up, 25 feet, silted up.

Forder Lake, G.W.R. viaduct, 66 feet, under 70 feet of silt.

Wivelscombe Lake 46 feet, under 56 feet of silt and mud.

At the G.W.R. viaduct across the Lynher (or Nottar Creek) 46 feet, under 55 feet of silt.

At the G.W.R. viaduct across the Tiddy (St. Germans River) 41 feet, under 50 feet of silt. Further west the railway crosses the Seaton and East Looe "rock valleys above the sea level, which have sections altogether similar to those of the valleys now partly below that level."

At a mile and a quarter from the mouth of Stonehouse Creek, where the valley is crossed by the railway viaduct, the rock bottom was encountered at 9 feet above low-water level under 5 feet of silt.

In the sections made during the construction of the Millbay Docks, the depth of the rock bottom was proved to be 73 feet below low water "opposite the outer pier, gradually shallowing to 48 feet at the wall of the inner basin, and then bending toward the entrance of the Old Union Dock, where [it] is 22 feet."

Mr. Inglis tells us that "in excavating for the foundations of a house in Union Street, near the boundary between Plymouth and Stonehouse, a full-sized anchor and part of a cable were discovered several feet underground."

The Millbay valley was formerly filled with silt to a depth of 55 feet at the outer end, and of 27 feet near the entrance to the Union Docks. In one section red clay and stones, about 3 feet thick, is recorded under the silt.

The narrow entrance to the Hamoaze at Devil's Point is 120 feet deep, with a slope of 1 in 2 from the Cornish side. "In Sutton Pool the rock side on the west slopes down at the rate of 1 in 2 to 60 feet below the level of low water."

Within 120 feet of the shore off the west pier on the outside of Sutton Pool rock was not encountered at 60 feet; within the piers a depth of 65 feet to rock bottom has been recorded.

When visited in 1898 the deepest boring at the Keyham Extension Works, after passing through made ground of slate rubble which for 30 years had compressed the mud beneath it, reached the slate rock bottom under 40 feet of mud.

On a subsequent visit, in company with Mr. Reid, in October, 1902, when the cope stood at 14 feet 6 inches below Ordnance datum, the deepest excavation, to 90 feet below low water of ordinary spring tides, showed a rock bed of grey-buff slates with a general southerly inclination of cleavage, overlain by estuarine mud with *Cardium edule*, Linn., *Scrobicularia* and *Mytilus* throughout, *Ostrea* in places, and a little drift wood (oak).

The rock floor was well exposed on its riverward slope near the north end of the works, where its surface is pitted with small shallow depressions or miniature rock basins. On the landward side piles of hazel and oak were visible, probably driven in for a small landing stage or jetty.

Worth[1] tells us that the original waterline before the construction of Keyham Docks left all the site of the docks except the north-eastern corner of what is now the north basin below high-water-mark, and at the south-western corner of the south basin the rock bottom was 50 feet below high-water spring tides and overlain by 25 feet of mud. The north-western corner of the north basin is a reef of rock (shown on the 6-inch map), visible at extreme low tides. Worth's informant told him that scarcely any vegetable remains were met with in the mud, except in one place between the two basins, where nearly a foot of peaty matter and an old blackened tree trunk were found. In excavating for the north basin a basal fragment of red deer antler 8 inches in length and circumference was "found about 7 feet below the surface," according to the label attached to it. It is supposed to have been used as part of a pick or the haft of a stone axe, and is figured by Worth, as also, for comparison, a deer horn pick of a much less rudimentary type obtained at a depth of 40 feet in the Carnon stream works.

Near the pontoon on the eastern side of Millbay at Sandycove, now obliterated, the occurrence of submerged forest traces has been recorded, by J. C. Bellamy,[2] but Worth was unable to obtain corroboration of this in excavations in the vicinity. R. Q. Couch[3] alluded to the discovery of cervine remains at Whitsand Bay, on the east of Looe, at Talland, and at Polperro beach. No particulars are given, and it seems legitimate to refer their occurrence to derivation from submerged forest grounds.

The tidal mud flats in St. John's Lake, Millbrook Lake, and in the Lynher Estuary (near Earth and Ince Castle), could no doubt to a considerable extent be reclaimed and converted into grazing land.

The coast between East Looe and Millendreath is most liable to waste, as it trends along the strike of the rocks which frequently dip seaward.

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[1] 'Raised Beaches and Submerged Forests,' *Trans. Plym. Instit.* and *Devon and Corn. Nat. Hist. Soc.*, 1885.

[2] 'Nat. Hist. of S. Devon,' p. 108.

[3] *Trans. Roy. Geol. Soc. Corn.*, vol. vii., p. 623.

The coast is more or less protected by the remains of the old beach platform; where this is not the case in Whitesand Bay there is a fine stretch of sandy beach. Mr. Inglis points out the variation in the beaches, in stormy and calm weather. "After a storm Kingsand beach will be raised two or three feet; the surface will be covered with fine sand and a few small pebbles." A continuation of calm weather lowers it, and it then consists of rough shingle. "The extent of the fluctuation is about five feet. The small beaches under the Hoe behave in a precisely similar manner. On the beach at the steps we have measured a general raising during a night of six inches on an ordinary storm, and the sand appears as at Kingsand."

CHAPTER VIII.

ECONOMICS.

WATER SUPPLY AND WELLS.

The water-works of Plymouth date from 1590, when Sir Francis Drake caused an open leat, or channel, nearly 18½ miles in length, to be constructed, by which the water was conveyed from the Meavy catchment basin, near the west border of Dartmoor, to the town. At first it was distributed in open channels, later on pipes were used, and reservoirs were established at Drake's Place, Crownhill, Hartley, and Roborough.

From the same area a contiguous open leat conveyed water to Devonport, and a reservoir was afterward made at Stoke. In 1864 the question of a storage reservoir was raised, and in 1887 and 1889 the Head Weir and Harter schemes were successively abandoned. At length, in 1892, the Corporation decided, on the recommendation of Mr. Sandeman, their water engineer, to commence the present works, by placing a dam in the Burrator gorge and thereby converting the broad valley above it into a lake a mile and a quarter long, covering 116½ acres and 77 feet in greatest depth. The gathering ground for this magnificent supply is rather more than eight square miles.[1]

Millbrook derives its supply from a reservoir placed in a valley at half a mile east of Withnoe, which impounds two small streams, the chief of which rises on the border of a patch of felsite of Withnoe and Cawsand type. East and West Looe obtain their supplies also by impounding streams in the vicinity, collected in reservoirs from 70 to 100 feet above datum.

Liskeard obtains its water from streams rising in the granite of Bodmin Moors, collected in a reservoir on St. Cleer Downs, and thence conducted to the town by gravitation. East of Liskeard, at Maudlin, rock similar to that of Clicker Tor is said to have been reached in a well sunk to a depth of 54 feet.

The Saltash supply is obtained from a deep boring put down at the bend in the road to St. Stephens at rather over half a mile west of Saltash Station, by Messrs. Isler and Company, to whom we are indebted for particulars of the deep well sinkings made by them at Saltash and Plymouth. The Saltash boring reached a depth of 412 feet, the strata successively encountered being as follows:—

	Ft.	In.
Slate	31	0
Slate and spar	3	0
Slate and stone	20	0
Slate	5	0
Slate and stone	6	0
Slate	2	0

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[1] 'The Burrator Reservoir,' *Trans. Plym. Inst.*, vol. xiii., 1899, p. 73, &c.

	Ft.	In.
Slate and stone	2	0
Slate	3	0
Slate and stone	24	0
Slate rock	284	0
Slate and spar rock	1	0
Slate rock	1	0
Slate and spar rock (quartz)	30	0
	412	0

Lined with 20 feet 10 inch tubes. Water level 8 feet from surface. The samples I have seen consisted of pulverized slate, the cores being unfortunately mislaid or destroyed. There is therefore no means of ascertaining whether volcanic rocks are included in the above section.

The following is an account of a well sunk for Messrs. F. R. Vaughan and Company at the Brewery, Saltash:—

	Ft.	In.
Dug well, through slate	46	0
Hard blue rock with white crystalized veins	14	9
Slate with water	66	9
Very hard blue rock with white crystalized veins, with water	14	0
Slate with water	33	0
	174	6

Lined with 45 feet 5 inch tubes.

Water level 42 feet from surface. Yield 2,500 gallons per hour.

I have seen a core of Plymouth limestone purporting to come from the deeper boring, unlabelled and evidently from a boring in Plymouth.

The detailed section of the Octagon Brewery well in Martin Street, Plymouth (already referred to p. 59) is as follows:—

	Ft.	In.
Pit (slate)	16	0
Red and blue limestone	29	0
Limestone	3	6
Red limestone	1	0
White and red spar	1	0
Rock	1	0
Grey limestone	10	6
Red limestone	1	0
White spar	2	6
Grey limestone	23	6
Red limestone	1	0
Limestone	12	0
Grey limestone	56	0
Red marl	19	0
Red marl	6	0
Grey limestone	7	0
Grey limestone	5	0
Red limestone	24	0
Grey limestone	1	6
Red limestone	7	6
Grey limestone	5	6
Red limestone	2	0
Grey limestone	44	6
Red limestone	26	0
Grey limestone	126	6
Limestone (at 447 to 449 feet fissured)	37	1
Total depth	469	7

Water level 5 feet from surface. Supply obtained at 183 feet at the rate of about 6,000 gallons per hour.

The chart of the Victoria Spa well, Bath Street, about 150 yards from the above, differs in one respect from Worth's account, (see p. 59) from which the mention of 37 feet of red slate has been omitted.

	Ft.	In.
Earthy clay slate	20	0
Limestone	150	0
Blue slate	20	0
Red sandstone	3	0
Red slate	37	0
Limestone	50	0
Sandstone	4	0
Red and blue slate	30	0
Dunstone	8	0
Earthy clay slate	20	0
Red sandstone	12	0

This is taken from the British Association Report of 1841.

Messrs. Isler & Co. "think that there is a strong reason to believe that many of the blue slates and red slates mentioned above are merely slaty limestones."

De la Beche[1] gives the following analysis of the Victoria Spring, by Professor Daniel :—

	Grains.
Chloride of sodium	96·64
Muriate of magnesia	18·68
Muriate of lime	15·10
Sulphate of soda	9·55
Sulphate of lime	8·94
Carbonate of lime	2·06
Carbonate of iron	0·69
	151·66

"Its specific gravity at 62° is 1013·3 and it contains 8·1 cubic inches of carbonic acid gas in an imperial wine pint."

A 10-inch boring was put down for the Plymouth Breweries, Ltd., at the Regent Brewery, Stonehouse, details as follows :—

	Ft.	In.
Pit	19	0
Limestone	5	0
Variegated marl	8	5
Limestone rock, red and white	36	4
Red marl and stone	10	0
	78	9

Supply plentiful.

A 3-inch boring put down at the Anchor Brewery, Stonehouse, the Public House adjoining the Toll Bridge, by Messrs. Isler and Co., yielded a plentiful supply of water. The details given are as follows :—

	Ft.	In.
Pit in made ground	3	0
Boring	109	0
Rock	4	6
Blue rock	13	6
Blue limestone	2	4
Blue rock	17	8
	150	0

Messrs. Polkinghorne's Bedford Street Brewery well was sunk by Messrs. Le Grand and Sutcliff. The details have already been given (p. 61).

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[1] 'Report,' pp. 517, 518.

The details of their Mutley Brewery well (1897) were communicated by Messrs. Le Grand and Sutcliff as follows :—

	Ft.	In.
Made ground	1	0
Shale	3	0
Shillet and clay	28	6
Shillet (hard) and Spar (rock almost vertical)	198	6
	230	6

Water-level varies from 2 to 9 feet.

There are numerous springs and shallow wells throughout the area. In the village of Antony a well not two feet deep has never been known to run dry.

MINES AND MINERALS.

Mining enterprise is practically extinct in the area embraced in Sheet 348, although copper occurs near the northern margin of the map, and important lead lodes have been extensively worked at Herodsfoot, Menheniot, and on the Devon shore of the Tamar, south-west of Beer Alston. Antimony was worked near Pillaton and Duloe.

Copper.—Near the metamorphic aureole on the north border of the map, at half a mile east of Trethinnick, a mine burrow, or dump, marks the site of an abandoned copper mine. No information was forthcoming in the neighbourhood. Its position, however, would lead to the inference that the easterly prolongation of the copper lodes on the south of, and near, St. Neots, thus far is probable. Messrs. Webb and Geach [1] mention a mine called Liskeard Consols worked by a Liskeard company prior to 1863, and abandoned after incomplete trial. The position, a little south of the greenstone on St. Cleer Downs, suggests identity with the above.

Lead.—The silver-lead lodes of North and South Hooe and of South Tamar Mine, on the Devon shore of the Tamar, are the earliest worked in the area. The former crosses the peninsula between Haltonquay and Holes Hole on the east of Ferry. South Hooe Mine is at the point where the lode leaves the Tamar coast half a mile west of Holes Hole; and North Hooe Mine west of Whitsom, where it passes under the river channel on the north, in a direction S.15°W. and N.15°E. The South Hooe Mine is said to have yielded as much as 140 oz. of silver to a ton of lead.[2] The South Tamar Mine is about 700 yards east of Weirquay on the Tamar bank, and from thence the lode runs N. 2° to 5° E., through Furzehill Mine and Lockeridge Mine, continuing for a considerable distance northward. The Tamar mines are said to have yielded £14,646 worth of ore at a cost £12,067, in 1841.[3] The water of the Tamar broke in and drowned the South Tamar Consols Mine in 1856.

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[1] Webb and Geach. 'The History and Progress of Mining in the Caradon and Liskeard Districts.' London 1863.

[2] De la Beche's 'Report,' p. 612.

[3] J. H. Collins, *Trans. Roy. Geol. Soc. Corn.*, vol. xii., p. 688, 1902.

The large proportion of silver associated with the lead in these ('the Beer Alston') mines was referred to by Dr. J. F. Berger in 1811.[1]

An adit suggests trial workings for lead at the bend in the stream north of Hole Wood and south-south-west of Collytown.

East of Whitleigh House, south-east of Tamerton Foliott, is Wheal Whitleigh, a disused silver-lead mine. The lode seems to be intersected by the adjacent road cutting, and an old shaft on the border of a tract in which numerous blocks of quartz rock occur on the surface may mark its continuation at more than half a mile to the north.

East of Botus Fleming old shafts (probably Wheal Hancock Mine), at about 180 yards up the Kingsmill Creek from Kingsmill Lake, mark the position of the most easterly lead lode in Cornwall at a place called Lower Moditonham.

An important silver-lead lode has been worked in Wheal Mary Ann, a quarter of a mile north of Menheniot, from thence it runs north, through Wheal Hony and Trelawny, for three-quarters of a mile to Trehane or Trehan Sett, whence with a very slight easterly deviation it seems to run northward for more than half a mile to Treweatha Mine, and thence in the same direction to the north border of the map on the west side of Trebeigh Wood.

Three-eighths of a mile east of Treweatha Mine is North Trelawny Mine, from which a lead lode runs north through Wheal Ludcott to Wheal Wrey silver-lead mine on the south border of Trebeigh Wood.

Mr. J. H. Collins[2] gives the average width of the Wheal Mary Ann Trelawny lode as four feet, with an easterly underlie of 60° to 80°. Volcanic rocks seem to have been encountered in the shafts. Mr. Giles[3] records carbonate and phosphate of lead in abundance in the shallow levels of Wheal Trelawny, also crystals of barytes. In the south part of Wheal Mary Ann he mentions the occurrence of a rock resembling elvan splitting upward into three branches, and of elvan associated with the lode at Trelawny. The late Sir C. Le Neve Foster[4] pointed out that there were at least two periods of formation of fluor spar in the Wheal Mary Ann lode, the lead ore being deposited in an intermediate period and the last minerals formed being quartz, chalybite, and calcspar. Mr. Collins[5] states that Wheal Trelawny was worked from 1844 to 1871, Mary Ann 1846 to 1876, Trehane 1843 to 1857. "The ores produced realised close upon one million sterling." A broad belt of 'slidy ground' was met with in following the lode southward.

The Ludcott and Wheal Wrey lode is said to resemble the Wheal Mary Ann lode, and to have a similar underlie. In Wheal Wrey large crystals of barytes and of fluor are recorded, and in parts of Wheal Ludcott "native silver, argentite, pyrargyrite, proustite, stephanite, &c., in very considerable quantities." Wheal Wrey Consols and Wheal Ludcott were old mines restarted in 1853 and 1856, and united between 1863 and 1866. "A run of 'slidy ground' running east and west, and locally termed a cross course," was found to be richly "interspersed with argentite." The Herodsfoot Mines were started more than a century ago, but re-opened about the year 1844, and worked more or less continuously until 1884. The earliest workings seem to have been in the tributary valley immediately west of Herodsfoot, and all the accounts procurable refer to the course of the lode [in Middle Devonian slates] to the north and south of this. Although South Herodsfoot silver-lead mine is directly in line, and said to be on a continuation of the lode, no information as to the materials passed through in the levels where the lode runs for a quarter of a mile in Lower Devonian is forthcoming. Mr. Collins says "the lode underlies to west about 1 in 6, and varies in width from a mere joint up to 3 or 4 feet." The quartz veinstone contained iron pyrites, blende and bunches of tetrahedrite.

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[1] *Trans. Geol. Soc.*, vol. i., p. 171.

[2] *Trans. Roy. Geol. Soc. Corn.*, vol. xii., p. 690–694.

[3] *Ibid.*, vol. vii., p. 198.

[4] *Ibid.*, vol. ix., p. 152.

[5] *Op Cit.*

At about 280 yards to the south of the old engine shaft (where the ore ground after re-opening in 1844 was followed down to about 900 feet) a belt of 'slidy ground' was encountered in the levels. "The whole strata," says Mr. H. C. Salmon,[1] "seems to be broken up by a succession of disturbances of a nature between cross courses and slides." This broken ground is said to obliterate the lodes, although sometimes containing detached pieces. "Its width in Herodsfoot is about 60 fathoms at surface and 30 fathoms at a depth of 150 fathoms."

"To the south of this belt of broken ground," says Mr. Collins, "as also south of a second 'run' subsequently met with near the new shaft, the ore was found to be much richer in silver than it had been to the north." From 1848 to 1862 the output of ore sold is given as 9,648 tons.

This lode is almost north and south and about a mile long, but lead lodes have also been worked on the east side of the valley at Herodscombe Mine under the Staddon grit outcrop. The shafts south of Herodsfoot Church suggest a north-west and south-east lode, and about 400 yards up the same tributary valley eastward there is another shaft probably in another lode. The 'slidy ground' may indicate disturbances parallel to thrusts affecting the Staddon grit outcrop; the information is, however, altogether too vague to base anything of structural importance on it.

Mr. MacAlister has supplied the following tables of the Mines, and their output.

The following table is an alphabetical list of the mines situated in 1-inch map 348, giving the parishes in which they occur, the numbers of the 6-inch quarter sheets (in Roman numerals and letters) and the numbers of the 25-inch maps.

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[1] *Mining and Smelting Magazine*, ii., p. 213.

MINE.	PARISH.	6-inch Map.	25-in. Map.
CORNWALL.			
Butterdon	Menheniot and St. Ive...	xxxvi., N.E.	3
East Herodsfoot ...	Duloe	xliii., N.E.	4
Hancock, Wheal ...	St. Dominick	xxx., S.W.	13
Herodscombe	Duloe	xliii., N.E.	4
Herodsfoot	Duloe and Lanreath ...	xliii., N.E.	4
Hony and Trelawny ...	Menheniot	xxxvi., S.E.	11
Ludcott, Wheal ...	St. Ive	xxxvi., N.E.	3
Mary Ann, Wheal ...	Menheniot	xxxvi., S.E	11
North Herodsfoot ...	Lanreath	xliii., N.E.	4
North Trelawny ...	Quethiock and St. Ive...	xxxvi., N.E.	3
Penhawger Mine ...	Menheniot	xxxvi., N.E.	3
Polrose Mine	Lanreath	xliii., N.E.	4
South Herodsfoot ...	,, ...	xliii., N.E.	8
Trehane, Wheal... ...	Menheniot	xxxvi., S.E.	11
Trelawny, Wheal ...	,, ...	See Wheal Trehane	
Treweatha Mine ...	,, ...	xxxvi., N.E.	7
West Wheal Mary Ann	,, ...	xxxvi., S.E.	11
Wrey, Wheal	St. Ive	See N. Trelawny	
DEVONSHIRE.			
Beer old Mine	Beer Ferrers (Ferris)...	See South Tamar	
Cleave and Birch Mine	,, ...	See South Tamar	
Furzehill Mine ...	,, ...	cxi., S.W.	14
Gold Street	,, ...	See Lockeridge Mine	
Hancock, Wheal... ...	,, ...	cxi., S.W.	10
Jenny, Wheal	,, ...	cxi., S.E.	11
Lockeridge Mine ...	,, ...	cxi., S.W.	10
Maristow Mine	,, ...	cxi., S.E.	15
North Hooe Mine ...	,, ...	cxi., S.W.	14
North Tamar Mine ...	,, ...	cxi., S.W.	10
South Hooe Mine ...	,, ...	cxi., S.W.	14
South Tamar Mine ...	,, ...	cxi., S.W.	14
Whitestone Down ...	,, ...	See Furze Hill Mine	

Output of Minerals, from 1848 *to* 1884.[1]

Mine.	Lead Ore.	Lead.	Silver.	Other Minerals.	Remarks.
	Tons.	Tons.	Ozs.		
Butterdon ...	2	1½	—	—	In 1857.
Herodsfoot ...	19,010	13,470	616,590	5 tons Wolfram in 1881. 17 tons of copper ore yielding 1 ton of copper between 1881 & 1884.	Lead ore from 1848 to 1884. Silver from lead produced between 1853 and 1884.
Hony and Trelawny	88	60	—	—	In 1883 & 1884.

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[1] Compiled from '*Mineral Statistics of the United Kingdom*,' 1848 to 1881, and *General Report and Statistics* (Home Office), 1882 to 1884. No minerals raised since 1884.

Mine.	Lead Ore.	Lead.	Silver.	Other Minerals.	Remarks.
	Tons.	Tons.	Ozs.		
Ludcott, Wheal ...	3,200	2,180	105,810	12 tons silver ore. 69 tons rich silver-lead.	1856 to 1862.
Ludcott and Wrey	1,870	1,255	81,580	87 tons rich silver-lead.	1863 to 1866.
Mary Ann, Wheal	29,600	20,132	1,126,130	—	Lead between 1848 and 1875. Silver from lead produced between 1854 and 1875.
North Herodsfoot	92	48	673	—	In 1881 & 1882.
North Wheal Trelawny (Wheal Wrey)	327	221	3,754	—	1852 to 1859.
North Wheal Wrey	10	3	72	—	1858.
Trehane, Wheal ...	4,220	2,767	57,650	—	Lead from 1848 to 1858. Silver from lead produced between 1853 and 1858.
Trelawny, Wheal	23,180	16,726	680,740	920 tons of iron pyrites. 7,230 tons arsenical pyrites. 460 tons of crude and refined arsenic.	Lead between 1848 and 1871. Silver from lead produced between 1853 and 1871.
Treweatha, Wheal	4,236	2,955	145,366	—	From 1853 to 1872.
Wrey Consols, Wheal	5,435	3,744	107,020	—	From 1853 to 1862.
Total ...	91,270	63,572	2,925,385	—	Lead since 1848. Silver since 1853.

D. A. MacAlister.

De la Beche[1] mentioned the discovery of antimony "in Pillaton about the year 1819, and 20 tons were raised in that year, 33 tons in 1820, and 79 in 1821." This information is derived from Lyson's (*Mag. Brit. Devon.*, p. 290) and leaves us quite in the dark as to the actual locality. There are some overgrown pits north of Dunstan, but a more probable locality is marked by an old shaft with a burrow of dark slate by the alluvium of the Lynher on the north-east of Crendle Down and opposite Newton Ferrers.

South of Duloe, and half a mile south-west of Tredinnick, there is a small quarry in grey slates with some dull greenish grit in which I was told that a small bunch of antimony had been discovered, probably along a W.S.W. and E.N.E.

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[1] 'Report,' pp. 616 and 615.

fault. There is a "lode at Tredinnick, near St. Urney, on the west of that place," mentioned by De la Beche and by Pryce (Mineralogia Cornubiensis, p. 47) as a mine near Saltash from which some (under 25) tons of antimony were obtained. There are remains of mine workings at Tredinnick, near St. Erney, called 'Old Lead Mines' on the 6-inch map.

BUILDING MATERIALS, &c.

All the Devonian subdivisions have furnished materials locally quarried for building purposes. The *Dartmouth slates* and associated grits have been quarried for local building, and wallstone, near Polperro, north of Downderry, east of Seaton Beach, and near Trewall.

The variable rocks of the *Meadfoot group* yield rough dark slate or flagstone quarried by the coast near Portnadler Bay, east of Pelynt, north and west of Hessenford, near Perdredda Wood, &c. The coherent laminæ of the fossiliferous shales, where joints permit of the extraction of fair sized blocks, has been taken advantage of for local building purposes, in quarries in the East and West Looe valleys, south of Hessenford, near Trelowia, south-west of Bake, near Trethill House and Trewrickle (near Sheviock), and on the west of Millbrook. Rough grits are quarried in them opposite Watergate in the West Looe valley. The arenaceous mudstone type of Barcelona quarry, worked to a depth of 40 feet, yields a fairly good building stone, as it splits into tolerably thick blocks and stands dressing. Generally speaking the patches of grit in this series shown on the map present here and there stone suitable for local buildings, outhouses, walls, &c.

The *Staddon grits* locally furnish a fair building stone, especially where the rock assumes the character of a dense arenaceous mudstone and can be worked freely, as is the case in some of the quarries by the West Looe valley, south of Herodsfoot, south of St. Keyne, and between Clicker Tor and Tregastick Wood.[1] There are also small quarries in this group south of Polbathick and near Maker, and in a large quarry above Staddon Point, hard evenly bedded grits exhibit conglomeratic bands.

The *Plymouth limestones* have been much used for flagstones, wall stone and building stones, and the pale red-veined and dark varieties furnish ornamental marble used in church decoration and monumental work. Large blocks of the limestone have been extensively employed in the construction of the breakwater. The chief limestone quarries are near Mount Wise, on the north-east, on Stonehouse Hill, near Millbay, at West Hoe, on the south side of Sutton Harbour, and at Mount Batten. Slates and flooring flags have been quarried on the north of Polbathick, presumably in Middle Devonian *slates* with a southerly cleavage dip of 80°, also at Roseland Quarry, west of Tregrill under an impure limestone bed, the cleavage being nearly horizontal. At Bokenna and Killatown Wood in the Fowey valley, at Trehunsey and Hepwell Bridge in the Quethiock district, at Kilquite near Tilland, at Catchfrench Quarry, east of Tideford Cross, at Borough Quarry west of Torpoint, dark slates, presumably in the lower part of the Upper Devonian, have been extensively quarried for rough slate, flagstone, wallstone, &c. The purple and green Upper Devonian slates have been quarried at Wivelscombe Slate Quarry and other places. There is, however, no slate in the district to compete with that of Delabole, the stone in the quarries mentioned being mostly used for flagging or rough building purposes. The Middle Devonian strata south of Liskeard and rocks of the same type west of Quethiock have been extensively quarried for local building stone. The coherence of the cleavage planes between readily separable floors give the rock a tolerably thick-even-bedded appearance and a certain density of texture. This type is quarried north-west of Bosent, south of Liggars, near Merrymeet, Trembraze, Island Shop (south-east of Liskeard), Ladye Park, Looe Mills. On the east side of the East Looe valley—south of Lamellion (at Combe Cottage), and south and west of Gormellick. On the west of the East Looe—between Moorswater and Lametton Mill, at Moorswater by the railway viaduct, west of Lamellion, at Trussel Bridge, and in numerous quarries by the tributary valleys between Boduel and Pounda. In these quarries the stone often splits, through more or less regular jointing, into prismatic blocks and yields large tabular masses in places. When laid with the cleavage planes horizontal these blocks make a very fair building stone. The Culm greywackes between Amy Down and Trewashford yield building stone (freestone), and have also been quarried near Crist, and Crocadon. The Elvan, near Collytown, and east of Lopwell, yields serviceable building stone.

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[1] These comprise "the arenaceous strata," "readily worked as freestones," "in the vicinity of Liskeard." De la Beche's 'Report,' p. 491.

The contemporaneous volcanic rocks are sometimes available for local building purposes, as for example the St. Germans schalsteins, the schalstein of St. Budeaux, and the schalstein tuffs north of Weston Mill, but as a rule the igneous rocks are mostly quarried for roadstone.

Roadstone.

The best materials are furnished by the hard dark greenstones, including the proterobases, dolerites, and diabases. The proterobases of Forder Creek and the banks of the Lynher (Grove, Treluggan, &c.) are largely quarried, and these and the diabase quarries at Burraton Coombe and Poldrissick are the most important roadstone quarries in the district, owing to facilities of transport. Nearly all the hard masses of greenstone and the harder and less schistose varieties of basalt (as in the quarry near Devonport Workhouse) have been quarried for road metal.

The Trachyte of Bin Down, and the elvan near Collytown and Lopwell, are used for road metal. The felsites of Cawsand and Withnoe have been largely quarried for the same purpose.

The Lower Culm cherts are quarried for roadstone near Amytree, north of Newton Ferrers, between Herod Down and Pillaton, east of Pillaton, north-west of Polborder, &c.

Lime.

The Plymouth limestone was formerly conveyed in barges up the river and estuaries and burnt for lime manure. This practice accounts for many disused lime-kilns met with far away from limestone. It is still shipped to parts of Western Cornwall to be burnt for lime for building purposes, &c. The large manure works of Messrs. Burnard, Lock and Alger are in the Catdown limestone, chiefly quarried in the adjacent map (349).

Bricks, &c.

In the brickyards of Inswork and Foss, by the inner end of Millbrook Lake, the Middle Devonian slates are crushed and used for brickmaking; they are associated with schalsteins which have also been crushed, but make very inferior bricks. The slates are grey, argillaceous, and buff-weathered. They are also quarried at Southdown for the same purpose. The surface slate on the north border of the limestone is worked for brickmaking, on the east margin of the map, at Sutton Pool harbour, and in the small brickyard by the cemetery near the reservoir at Stoke. At Hannafore Point, near West Looe, the low cliffs are composed of from 10 to 15 feet of Head of pale yellowish-brown loam with local stones mostly small. This material was used for brickmaking in a brickyard at the Point.

Clays.

Clay suitable for puddling is encountered south-east of Liskeard at the head of a valley on the east of the high road near Cartuther, between St. John's and Penhale, and south of St. John's at about a mile east of Higher Tregantle, probably on a fault line. By Bladderly Lane, near Ivy Cottage, north of the quarry near Devonport Workhouse, Mr. S. Newton, the surveyor, informed me that a vein of good puddling clay had been encountered.

Although no china clay occurs in Sheet 348, the foundation of the china clay industry was established in Plymouth by Cookworthy. Among masses of granite brought from Tregoning Hill, in Breage, for the construction of casemates in the Citadel, he detected the china stone, or petuntse of the Chinese, between 1745 and 1750, and took out "his patent for the manufacture of Plymouth china in 1768."[1]

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[1] See Paper by R. N. Worth, 'The Clays and Fictile Manufactures of Devon and Cornwall.' *55th Ann. Rep. of Roy. Corn. Polytechnic Soc.*, 1887.

Paint.

The purple and green Upper Devonian slates of Wivelscombe quarry are now worked. After being ground up and mixed with other materials they produce a deep red pigment.

AGRICULTURE.

The natural capabilities of the soils in Sheet 348 are very variable. The Dartmouth slates, and the Upper Devonian slates, where not associated with calcareous material (as in the Botus Fleming valley), or with contemporaneous or intrusive igneous rocks, often make very thin soils, but this is much less frequently the case in the more variable materials of the Meadfoot group. In the volcanic districts, on the other hand, between Plymouth and Liskeard, the soil is often thick and rich. Until recent years town manure was so extensively used on the shores of the Tamar and its tributaries, that pure country air became mythical. There is more grazing than arable land in the area, but in the volcanic districts the latter often predominates. Strawberries are grown with success on the steep slopes of the Upper Devonian slates, between Halton-quay and St. Mellion.

APPENDIX.

List of Principal Works on the Geology of the District.

1802. Playfair, Prof. J.—Illustrations of the Huttonian Theory of the Earth. 8vo. Edin. (Reprinted in 1822 in vol. i. of Playfair's Works. 8vo. Edin.) Devon, pp. 152, 161, 212, 368–370; pp. 162, 174, 219, 365–7 of the later edition.

1811. Berger, Dr. J. F.—Observations on the Physical Structure of Devonshire and Cornwall. *Tr. Geol. Soc.*, vol. i., pp. 102, 103, 114–117, and 171.

1817. Hennah, Rev. R.—Observations respecting the Limestone of Plymouth. *Tr. Geol. Soc.*, ser. i., vol. iv., p. 410.

Home, Sir E.—An Account of some Fossil Remains of the Rhinoceros, discovered by Mr. [Whidbey] Whitby in a cavern enclosed in the limestone rock from which he is forming the Breakwater at Plymouth. *Phil. Tr.*, vol. cvii., p. 176.

1821. Hennah, Rev. R.—An Account of the Limestone of Plymouth. *Tr. Geol. Soc.*, ser. i., vol. v., p. 619.

Sedgwick, Rev. Prof. A.—On the Physical Structure of those Formations which are immediately associated with the Primitive Ridge of Devonshire and Cornwall. *Tr. Camb. Phil. Soc.*, vol. i., p. 89.

Whidbey, Jos.—A farther Account of Fossil Bones discovered in Caverns enclosed in the Limestone Rocks at Plymouth. *Phil. Tr.*, vol. cxi., p. 133.

1822. Hennah, Rev. R.—A Succinct Account of the Lime Rocks of Plymouth. 8vo. Plymouth and London.

1823. ———Letters on the Question of the Existence of Veins in the Limestone of Plymouth. *Ann. Phil.*, ser. ii., vol. v., pp. 310, 471.

Prideaux, J.—[Letter] On the Question as to the Existence of Metallic Veins in the Transition Limestone of Plymouth. *Ibid.*, p. 310.

1827. Hennah, Rev. R.—Additional Remarks on the Nature and Character of the Limestone and Slate principally composing the Rocks and Hills round Plymouth. *Proc. Geol. Soc.*, vol. i., p. 1.

1829. ———*Tr. Geol. Soc.*, ser. ii., vol. ii., p. 405.

1830. ———On the Animal Remains found in the Transition Limestone of Plymouth. *Proc. Geol. Soc.*, vol. i., p. 169.

Prideaux, J.—Geological Survey of some parts of the country near Plymouth. *Tr. Plymouth Inst.*

1837 and 1839.—Sedgwick, Rev. Prof. A., and [Sir] R. I. Murchison.—On the Physical Structure of Devonshire and on the Subdivisions and Geological Relations of its older stratified Deposits. *Tr. Geol. Soc.*, ser. ii, vol. v., parts i. and ii., pp. 633–687 and 688–703. (See also *Rep. Brit. Assoc.* for 1836. *Tr. of Sections*, p. 95.)

1838. Sedgwick, Rev. Prof. A.—A Synopsis of the English series of stratified rocks inferior to the old red sandstone—with an attempt to determine the successive natural groups and formations. *Proc. Geol. Soc.*, vol. ii., p. 675.

1839. De la Beche, [Sir] H. T.—Report on the Geology of Cornwall, Devon, and West Somerset. (*Geol. Survey*), 8vo. London.

Bellamy, J. C.—The Natural History of South Devon. Chaps. ii., iii., and iv. Geological. 8vo. Plymouth.

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1840. Lonsdale, W.—Notes on the Age of the Limestones of South Devonshire. *Tr. Geol. Soc.*, ser. ii., vol. v., p. 721.

1841. Moore, E.—On the discovery of Organic Remains in a raised beach in the Limestone Cliff under the Hoe at Plymouth. *Rep. Brit. Assoc.* for 1841. *Tr. of Sections*, pp. 62-3.

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Couch, Richard Q.—On the Silurian remains in the strata of the south-east coast of Cornwall. *Ibid.*, p. 147.

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1847. Couch, Richard Q.—Remarks on the present state of the Geology of Cornwall. *Ibid.*, vol. vii., p. 13.

1848. Peach, C. W.—On the Fossiliferous Strata of part of the South-east Coast of Cornwall. *Ibid.*, p. 57.

1849. Giles, J.—On the Fossiliferous Rocks of the Liskeard District. *Ibid.*, p. 93.

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Pengelly, W.—On the Icthyolites of East Cornwall. *Ibid.*, p. 115.

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Pengelly, W.—Remarks on the Geology of the South Coast of Cornwall. *Ibid.*, p. 211.

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1853. Edwards, H. M., and J. Haime,—A Monograph of the British Fossil Corals. Part iv. *Pal. Soc.*, pp. 211-244.

1854. Couch, Jonathan.—On a supposed new species of the Fossil genus *Astræa* found in Cornwall. *Tr. Roy. Geol. Soc. Corn.*, vol. vii., p. 244.

————Description of the Fossils found in a quarry near Trelawny, in the parish of Pelynt, Cornwall. *Ibid.*, p. 249.

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1855. ————Notes on the Foliation and Cleavage of the Cornish Slates. *Ibid.*, p. 273.

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1858. Whitley, N.—On the Strike of the Slate-beds in Cornwall and Devon. *Ibid.*, p. 336.

1861. Pengelly, W.—The Geographical and Chronological distribution of the Devonian Fossils of Devon and Cornwall. *Ibid.*, p. 388.

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1863. ————A Monograph of the British Devonian Brachiopoda. *Ibid.*, vol. xvii. no. 2.

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————Building Stones of Devon and Cornwall. *Ibid.*, no. 8, p. 120.

1872. Pattison, S. R.—On the Upper Limits of the Devonian System. *Proc. Geol. Assoc.*, vol. ii., no. 7, p. 277.

1874. Foster, [Sir] C. Le Neve.—Remarks on the Lode at Wheal Mary Ann, Menheniot. *Tr. Roy. Geol. Soc. Corn.*, vol. ix., p. 152.

1875. Worth, R. N.—The Geology of Plymouth. *Tr. Plymouth Inst.*, vol. v., p. 450.

1877. Inglis, J. C.—Plymouth Sound—its Tidal Currents. *Ibid.*

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Ussher, W. A. E.—Notes on the Pleistocene Deposits of the Cornish Coast near Padstow, Plymouth and Looe. *Ibid.*, p. 58.

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1882. Davidson, T.—Supplement to the British Devonian Brachiopoda. *Pal. Soc.*, vol. xxxvi.

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1883. ————On Trowlesworthite, and certain Granitoid Rocks near Plymouth. *Ibid.*, p. 177.

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1889. ————Geological Notes on the South-Western Line between Lydford and Devonport. *Tr. Devon. Assoc.*, vol. xxi., p. 261.

Ussher, W. A. E.—The Devonian of the Western Region, and Geology of Tavistock. *Ibid.*, p. 437.

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315 - - - SOUTHAMPTON. By C. Reid. *1s. 6d.*
317 - - - CHICHESTER. By C. Reid [and Others]. *1s.*
325 - - - EXETER. By W. A. E. Ussher. *2s.*
326 & 340 - SIDMOUTH and LYME REGIS. By H. B. Woodward and W. A. E. Ussher. *1s.*
328 - - DORCHESTER. By C. Reid. *1s.*
329 - - BOURNEMOUTH. By C. Reid. *4d.*
332 - - - BOGNOR. By C. Reid. *6d.*
334 - - - EASTBOURNE. By C. Reid. *6d.*
346 - - - NEWQUAY. By C. Reid and J. B. Scrivenor. *3s.*
348 - - PLYMOUTH and LISKEARD. By W. A. E. Ussher.
350 - - - TORQUAY. By W. A. E. Ussher. *2s.*
351 & 358 - LAND'S END DISTRICT. By C. Reid and [illegible]
352 - - - FALMOUTH and TRURO and MINING DI[illegible] B. H[illegible] and